SEPTEMBER 1957

THE WELDING JOURNAL

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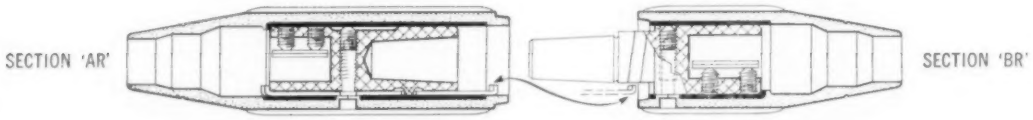

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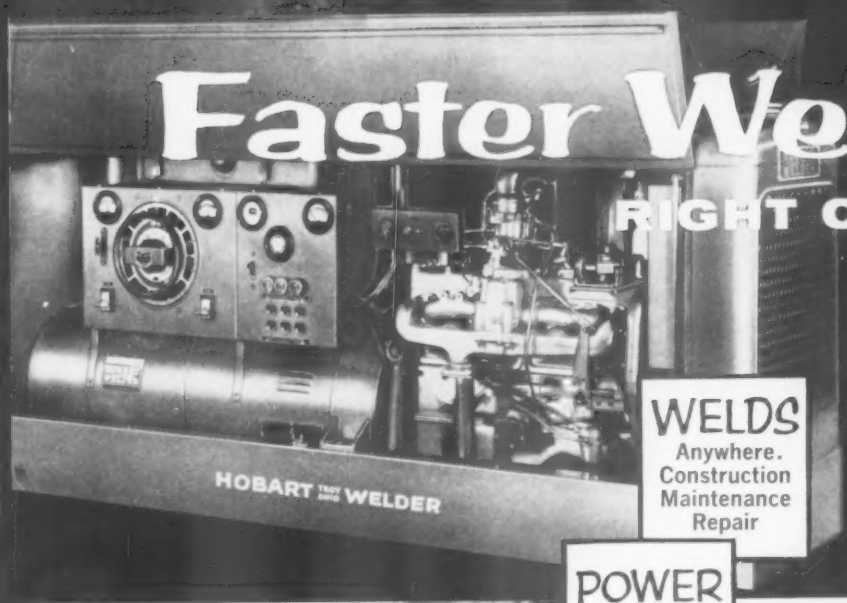

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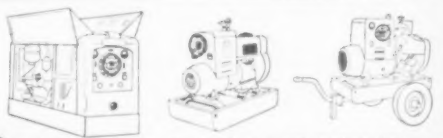

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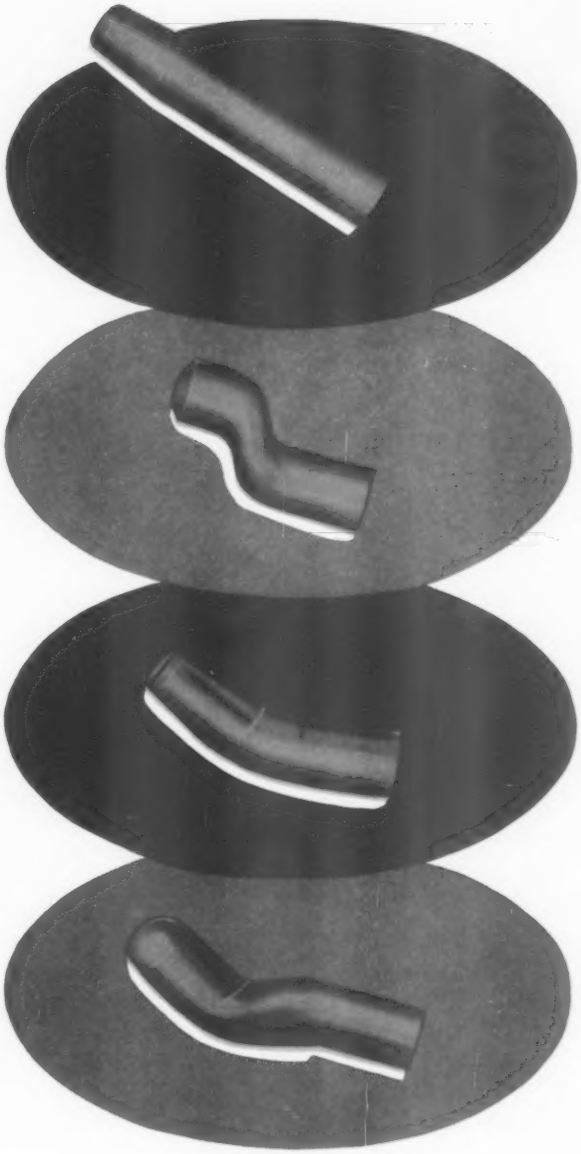

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The AMERICAN WELDING SOCIETY was founded some thirty-eight years ago as an agency for coordinating welding activities, and for assembling and distributing knowledge relating to welding. Since then, it has been singularly fortunate in having outstanding leaders from industry serve as national officers, providing guidance and inspiration of the highest quality. It has also been fortunate in recruiting qualified staff members who have served efficiently and effectively.

This combination of sound leadership and dedicated service has resulted in our SOCIETY of today, with almost 13,000 members and 82 local sections representing all interested in advancing the use of welded fabrication.

Upon joining the AWS headquarters staff, your new National Secretary has been pleased to find a group of industrious and alert young men, capable and well trained, who are directing or coordinating the varied activities of the SOCIETY. He looks with pride at a yearly exposition which is recognized as one of the largest and best; national meeting activities including awards, technical programs and social events; the membership activities involved in serving districts, sections and our individual members; technical activities which produce a steady flow of codes and standards of tremendous value to industry and to the public; a publication activity which produces a JOURNAL which is acclaimed throughout the world as one of the finest technical magazines; a Handbook activity which involves the yearly production of 500 pages of authoritative information on some phase of welding; an educational activity which is now receiving significant staff support for the first time; office activities including the handling of thousands of accounts, purchasing, selling, a heavy volume of correspondence and other office routines; and a proposed welding information activity now under consideration by a special subcommittee of our Manufacturers Committee.

We have every reason to feel confident that the AMERICAN WELDING SOCIETY will continue to serve industry and the public welfare, expanding its activities to meet each new challenge presented by our rapidly developing economy.

Fred L. Plummer,
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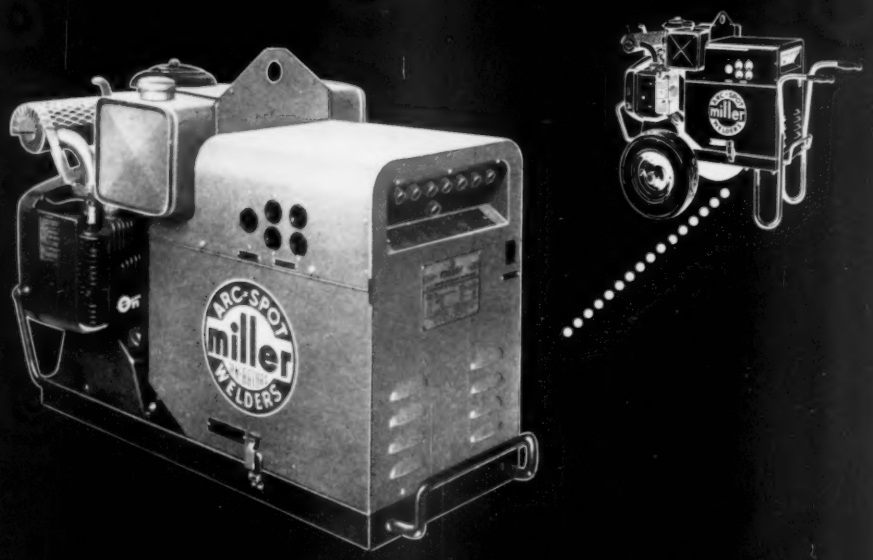

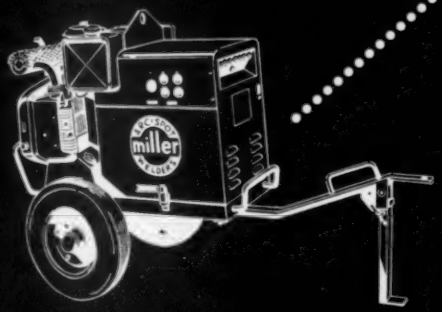

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Fig. 1 Platform view of welding operation

INERT-GAS TUNGSTEN-ARC SPOT WELDING OF AN AUTOMOTIVE TRANSMISSION SUBASSEMBLY

Use of high-production equipment to effect a multiple number of spot welds found to assure uniform product quality and satisfactory welding results

BY W. G. MERTENS AND O. J. RYDER

INTRODUCTION. The Detroit Transmission Division introduced a redesigned transmission for the model year of 1956. While the main purposes for redesigning the transmission were to simplify its operation and improve the smoothness of shifting, the possibility was also considered of adapting higher production methods, thereby reducing cost.

Basically, the "Hydramatic" transmission consists of two sections—the fluid coupling and the change-of-gear section. The former actually takes the place of the old clutch in the automobile. The latter contains a front unit and a rear unit which together accomplish the changes of ratio—through first, second, third and fourth gears—by means of clutches, clutch plate operations and brake band operations. In redesigning the change-of-gear section, a small fluid coupling was substituted for one of the friction clutch plate assemblies in the front unit. Other changes were also made which improved the transmission but are not pertinent to this paper.

As shown in Fig. 2, the small fluid coupling is approximately 7 in. in diameter and is composed of two similar torus shell assemblies—one with 20 vanes inserted and equally spaced, the other with 21 vanes inserted and equally spaced. The vanes are joined to the torus shells by inert-gas tungsten-arc spot welding, using a thoriated-tungsten electrode as the welding agent and argon gas to provide an inert atmosphere. This figure also illustrates

W. G. Mertens is Chief Metallurgist and **O. J. Ryder** is Supervisor of Weld Engineering at Detroit Transmission Division, General Motors Corp., Detroit, Mich.

Presented at 1957 AWS National Spring Meeting, Philadelphia, Pa., April 8–12.

Fig. 2 Oblique view of welded parts showing spot welds

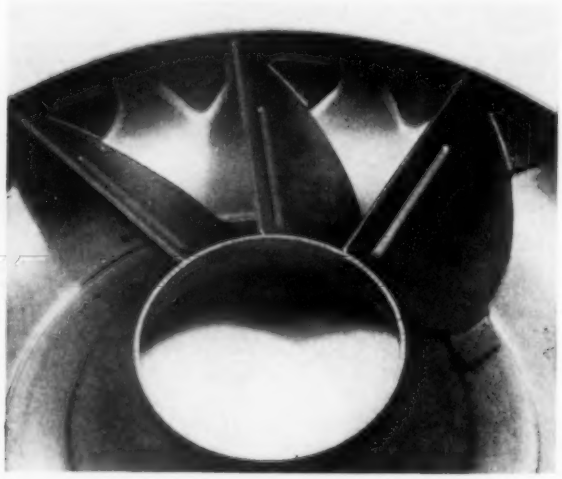

Fig. 3 Close-up of vane and shell

Fig. 4 Side view of machine with guard removed from torches

the two series of spot welds used to join the vanes to the shell—one series around the outer periphery of the shell and another series around the top of the shell. About 5000 transmissions, requiring 410,000 spot welds, are produced in a 16-hr day. Figure 3 is a close-up view showing several vanes as they fit into the shell.

The major theme of this paper is the application of the inert-gas tungsten-arc spot-welding process, through the use of high-production equipment, to produce a multiple number of spot welds on the automotive transmission subassembly—with uniformity of production quality and assurance of satisfactory welding results.

Fabrication Problems

Design Requirements

To improve the shift-feel characteristics of the transmission, the fluid-coupling-type clutch had to be substituted for the normal friction-type clutch. For practical purposes, it had to be designed to occupy a minimum of space and still produce the required efficiency. Development of the coupling was influenced by vane location, vane contours, number of vanes, and the need for an oil-tight assembly. In addition, the vanes had to be assembled in the shell in such a way as to transmit the required amount of torque. (In this assembly, each vane is subjected to $5^1/_2$ ft-lb of torque load at full engine torque; but, due to shock loading, this may increase to about 100% overload).

Survey of Methods

To mass-produce this unit at a reasonable cost, a method of assembly had to be developed which would be fast and yet require a limited amount of labor. Four types of fabrication were originally considered:

1. Mechanical crimping.
2. Brazing.
3. Combination of both mechanical crimping and brazing.
4. Resistance spot welding.

In surveying the several methods possible for fabricating this unit, mechanical crimping was considered first: slots would have been pierced in the shell; the vanes fastened into these slots with tabs extending be-

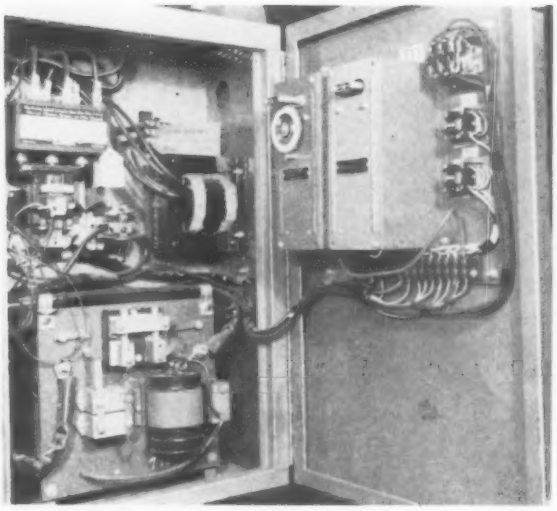

Fig. 5 Control box over machines

yond the shell; and these tabs bent over to hold the vanes in place. Mechanical crimping was not acceptable however, because it could not meet the oiltight requirement—oil could seep out through the slots. Furthermore, dimensional factors interfered with development of an acceptable design.

Brazing the assembly was considered next, but the contour of the vanes was such that it would have been almost impossible to position them and maintain them in position during brazing. Also, under conditions of fixture brazing, there would always have been the possibility of a missed-braze which would be very difficult to correct. While it would have been possible to combine the mechanical crimping and braze assembly methods, the combination of two operations would have entailed additional machine, furnace and labor costs.

Therefore, it was decided to weld the assembly. Resistance spot welding was considered, but would have required destructive testing for inspection. In an assembly of this type, containing a high number of spot welds, each weld must be dependable. If a vane comes apart due to a loose weld, it will very quickly ruin the whole assembly.

Solution

Mechanized inert-gas tungsten-arc spot welding was finally selected because it provided the basis for the high-production, high-quality type of welding necessary to produce a satisfactory assembly. In addition, the process permitted visual weld inspection. A side view of the machine is given in Fig. 4, disclosing: the fixture, parts to be welded, welding guns, welding head, ground ring and brush and argon and water lines.

The equipment actually consists of four individual machines which have produced approximately 65,000,000 spot welds on the subassembly since the introduction of the redesigned transmission. Each machine has two heads, with either four or six welding torches per head. With the four machines that are in use, there are 40 welding torches in operation. Normal production on a four-gun head machine is 150 welded assemblies an hour, while on a six-gun head machine it is approximately 190 an hour.

Figure 5 shows the control boxes over the machines. Also located over the machines are the high-frequency units and associated relays, and the rectifiers. Due to the use of high-frequency starting for this process, the complete installation had to be enclosed in a shielded area—the transmission plant being within $^1/_4$ of a mile from Willow Run Airport outside of Detroit, Mich.

Present Fabrication

Cleaning Parts

Cleaning of the parts is the first step in the subassembly fabrication. The vanes are brought in tote boxes to the washing machine, shown in Fig. 6. They are automatically removed from the tote boxes, dropped

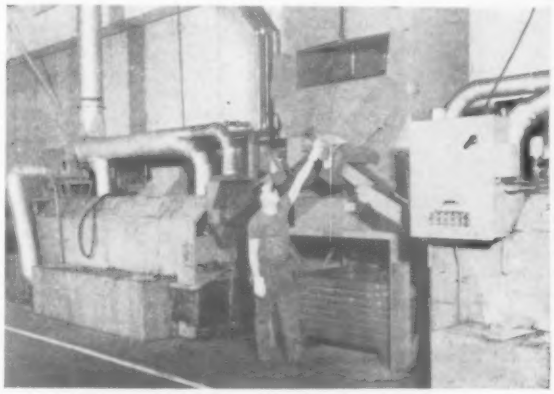

Fig. 6 Setup for washing vanes

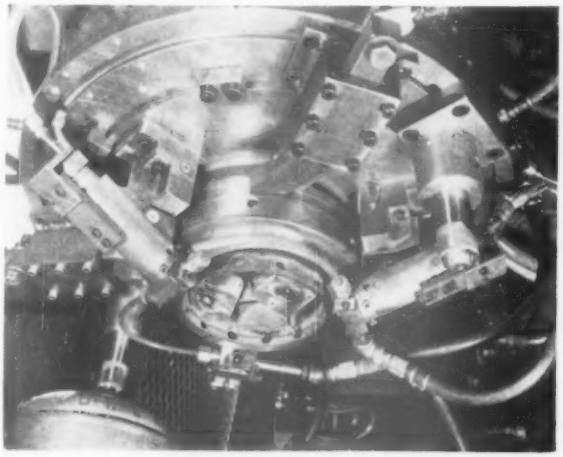

Fig. 7 View from bottom of six torches on machine

through the tumbling type washer, dried and dropped on a belt conveyor which transported them into the welding room. This is shown in Fig. 1, a general view of the welding machine.

Similarly, the torus shells are hung on a conveyor and carried through the washing machine, through a dryer and into the welding room. There, the two parts are

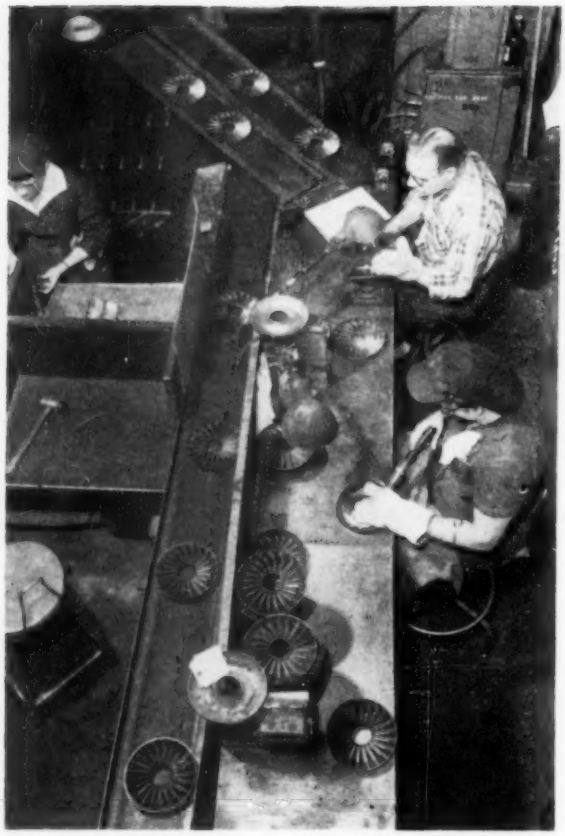

Fig. 8 Inspector in action

prepared for the welding operation. The vanes are stacked by an operator so that they can be inserted readily in the fixture; this stacking operation provides a type of inspection since it reveals any bad tab conditions which may accidentally exist.

Welding Operation

To operate one of the welding machines, a team of three women cooperate to load the vanes in the fixtures; inspect the fixtures to make certain the vanes are properly loaded; put the torus shells over the vanes; and unload the welded assemblies from the fixtures after the welding operation has been completed.

The cycle of the machine is automatic and the operators can perform the fixture-loading operation within the cycle time. If the need arises, however, the machine can be stopped by pushing a button. In addition, an automatic interlock is provided to stop the machine if it has not been properly loaded.

Operation of the machine can be described in eight distinct steps:

1. Machine indexes to the weld position.
2. Welding head and guns are lowered into position.
3. Lowered clutch under the table of the machine rises to contact the fixture.
4. Fixture makes one index, initiating the weld cycle.

Fig. 9 Close-up of missed weld on inside edge of torus shell

5. With guns in position, each weld is made and then the fixture is indexed.
6. This is repeated for the proper number of welds— either seven or ten welds depending upon whether a 21- or 20-vane assembly is being produced. The welding head has either four or six guns in order to get the proper index relationship for the number of vanes per assembly.
7. Lower clutch disengages, welding head rises and machine indexes out of position.
8. Built-in ejector rises, permitting operators to easily disengage and remove the parts.

Figure 7 shows a view looking up into the welding head showing a 6-gun welding head. During the operation, the argon flow rate is held to approximately 6 to 10 cfh. Power settings are 150 to 160 amp and 9 to 11 v, with a weld cycle time of 100 to 110 cycles. Current used in the welding operation is direct current, straight polarity.

Postweld Inspection

After unloading, the part is transferred on a slide to the inspector who visually checks each weld, as shown in Fig. 8. The inspector judges weld quality from the appearance of the weld nugget on both the inner and outer periphery of the weld. It is relatively simple to determine weld quality, since the presence of a nugget on the underside of the weld is the only indication necessary. Size of the nugget is not particularly important—up to 900 lb shear strength in the weld can be obtained with a minimum amount of nugget. This is far in excess of the strength required for the part.

If a weld has been missed, the inspector marks it and passes the part to the repair operator sitting next to him, as illustrated in Fig. 8. Using a manual inert-gas tungsten-arc spot-welding torch, the operator repairs the weld and passes the part to the inspector for approval. Since the equipment has been in operation, it has allowed less than 1% missed welds. Figure 9 shows the difference between proper weld nuggets and missing welds.

As further assurance of quality, the finished assembly

Fig. 10 Machine for proof-load test

is subjected to a proof-load test in the machine shown in Fig. 10. In this test the parts are put together, one part anchored, the assembly loaded with oil and the free part spun against the anchored part—thus subjecting the assembly to a proof-load test of about 50% above the maximum requirements of the transmission.

Critical Factors

Cleanliness of Parts

Since the vanes and torus shells are stampings, they require cleaning to remove drawing compound and rust-preventive oil. This prevents electrode contamination and porous welds caused by smoke from the oil during welding.

Torch Positioning

As a result of original development of the machine, the electrode holders or torches, shown in Fig. 11, are carefully positioned to make sure that: (1) the inert argon gas provides proper protection for the weld, and (2) the direction of the arc is uniform and properly placed. This illustration is a mock-up of the 4 guns in their relative welding positions.

Electrodes

Electrode-to-work distance is carefully controlled, the ideal distance being 0.060 to 0.080 in. Any distance beyond 0.080 in. produces incomplete weld penetration, while setting the electrode closer to the work than 0.060 in. results in possible weld burn-through. A blunt-nosed electrode would allow the arc to wander, causing incomplete penetration and misplaced welds. Therefore, the electrodes used are $^1/_8$-in. diam with the end "dressed" or tapered to $^1/_{16}$-in. diam to insure proper arc direction. Normal life expectancy of an electrode, between dressings, is approximately 2000 welds.

Welding Controls and Timers

Within certain limited parameters of arc time and welding current, 100% weld soundness can be expected. As these limits are exceeded, the number of poor welds is increased. This fact is illustrated by the graph in Fig. 12, showing the relationship of arc time to welding current. Because of these limitations, timing and current control equipment had to be developed. Machine

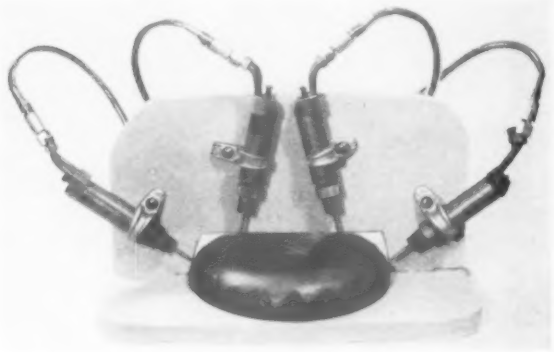

Fig. 11 Mock-up of torch over work

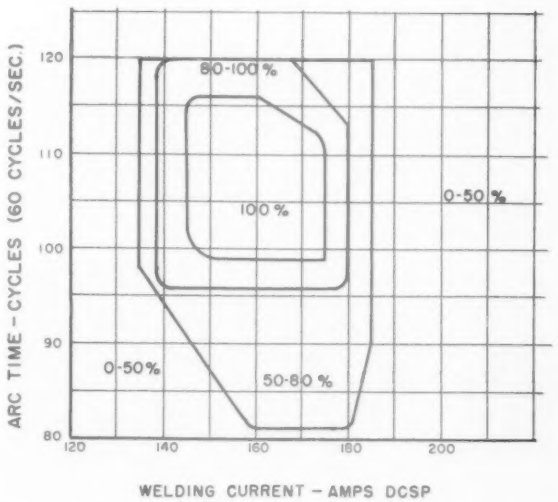

Fig. 12 Effect of arc time and current on weld consistency

settings of 150 to 160 amp and 100 to 110 cycles are required to produce 100% weld soundness; these controls are locked on the machines and are adjusted only by the welding engineer or the maintenance electrician.

Fixture

General Description and Function

As shown in Fig. 13, good welds can be maintained with a spacing between the parts as high as 0.006 in. As this limit is exceeded, however, the percentage of good welds drops—with 0.008-in. spacing producing about 90% good welds and 0.010-in. spacing approximately 80% good welds. Based on this knowledge, it was necessary to make a fixture to hold the parts that would keep the spacing relationship to a maximum of 0.006 in.

The fixture, illustrated in Fig. 14, is composed essentially of a machined base plate with 20 or 21 inserts as required to fixture the vanes. In addition, a center taper and cone arrangement is provided which allows outward movement of the inserts, thus correcting for wear and subsequent remachining to the proper diameter.

In loading the fixture with vanes, a pocket is provided in each insert to guide the vanes into position. Combined with the insert is the spring, which keeps the vane at a higher angle than normal for the assembly. As the vanes are loaded, they are somewhat higher than they would be normally in the torus shell assembly.

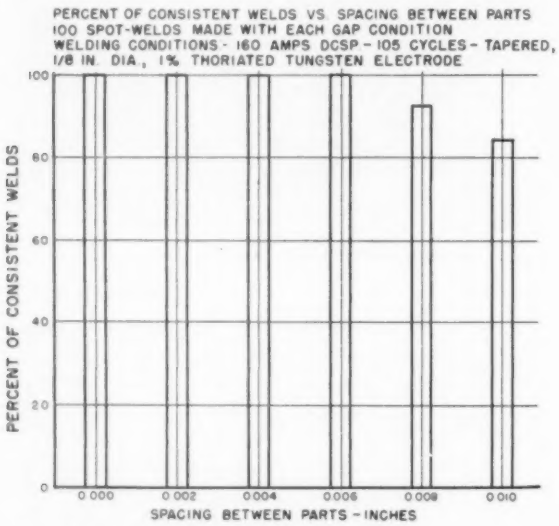

Fig. 13 Effect of fit-up on weld consistency

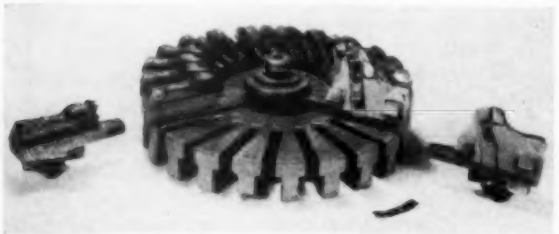

Fig. 14 Over-all view of fixture

Thus, after the torus shell is placed over the vanes, the welding head pushes the shell down to the vanes—insuring tightness of spacing between the shell and vane heads.

This fixture is an extremely important factor in the welding operation. First, it must hold the assembly in a way necessary for meeting the dimension requirements. Second, it must maintain the maximum 0.006-in. spacing of the parts necessary for producing a satisfactory weld.

Operator Training

No particular skill is necessary for loading the fixtures—operators need only to properly insert the correct number of vanes and place the torus shell on top of the assembled fixture.

Certain skills are required, however, to maintain proper welding conditions. The "set-up" man must observe the condition of the welds, note any electrode deterioration and change electrodes to prevent unnecessary missed welds. Also, he must be trained to properly set electrodes, since electrode-to-work distance between 0.060 and 0.080 in. is vital to maintaining good welding conditions. After a relatively short time of experience, however, the operator can maintain the proper welding conditions. A definite aid in maintaining electrode distance is gained by the fact that the voltage is directly related to the gap distance. A 0.060 gap results in an arc voltage of 9.0 v and an 0.080 gap results in an arc voltage of 11.0 v.

The inspector is readily trained for his operation, since his is strictly a visual requirement—noting the number of welds and type of nugget. Inspection requires only one or two glances to note all conditions of the parts. Little operator training is needed for repairing missed welds: the operator simply uses a manual inert-gas tungsten-arc spot-welding torch to make the necessary welds, all welding conditions having been decided upon previously by the welding engineer.

Conclusion

Primarily, the objective of this operation is the production of a multiple number of spot welds which can be inspected readily and can be relied upon for high quality. To produce this result, several factors require special consideration:

1. Cleanliness of the parts to be welded.
2. Proper development and maintenance of the fixture.
3. Proper control of electrodes and operating portions of the torches and guns.
4. Careful consideration of the machine's control factors—such as gas flow, power input and time cycle.
5. Efficient maintenance of equipment to keep the operation geared to its high production rate.

To date, more than 65,000,000 sound spot welds have been produced in this application. The use of inert-gas tungsten-arc spot welding has satisfied the two most important production requirements—low cost and quality.

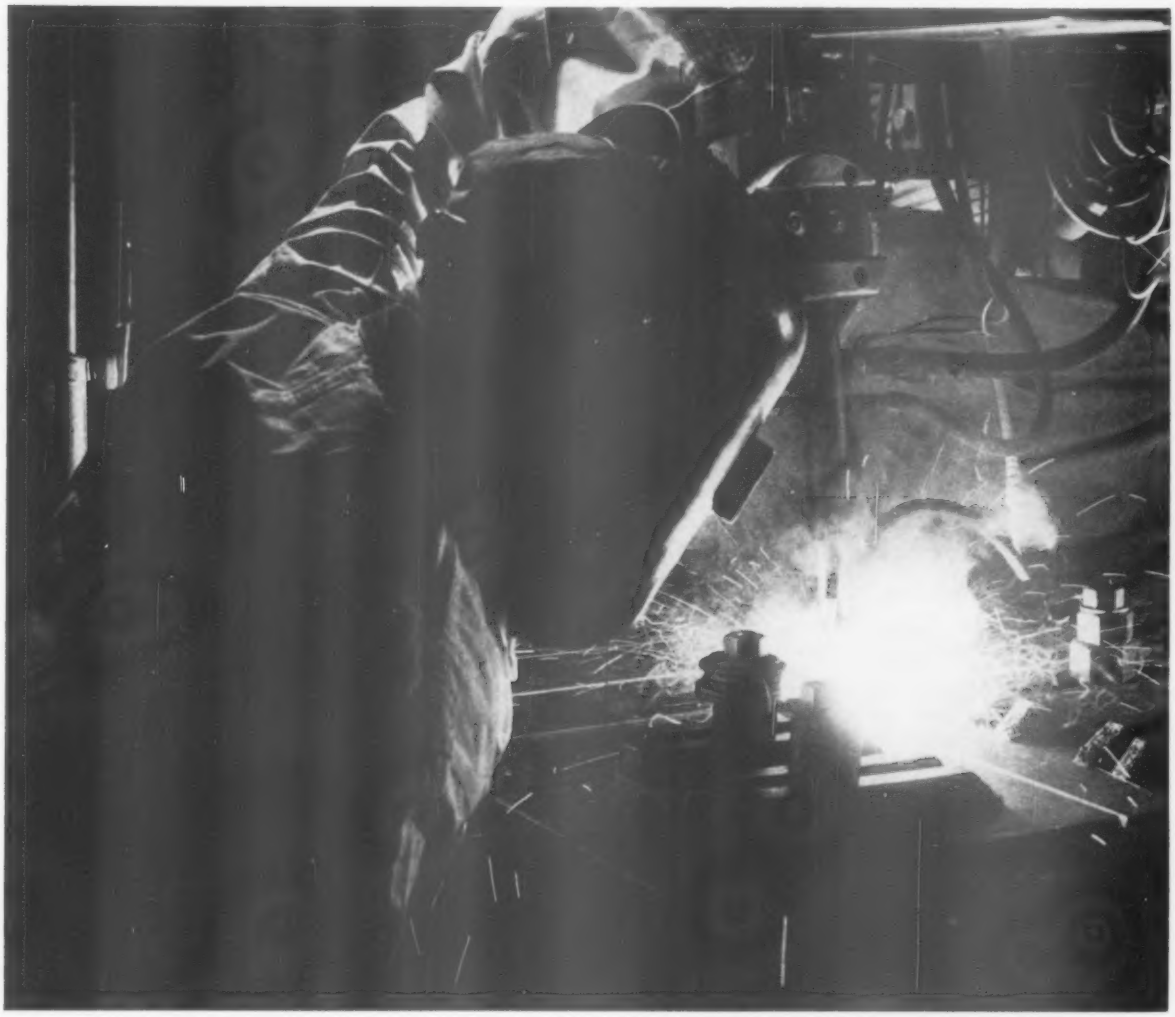

Fig. 1 An automatic gas-shielded consumable-electrode welding machine being used to make a butt weld on 1-in. ASME boiler plate, using carbon-dioxide shielding gas

BOILER-CODE WELDING AND JOINT DESIGN WITH THE CO_2 PROCESS

Investigation shows that quality welds can easily be made with carbon-dioxide gas-shielded process to meet the unfired-pressure-vessel code requirements

BY J. D. CAREY, JR.

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Presented at 1957 AWS National Spring Meeting in Philadelphia, Pa., April 8–12.

Introduction

Since carbon dioxide has been widely accepted as a shielding gas for the consumable-electrode welding of mild steel, it follows that boiler-code welding be considered an area of application. It has long been recognized that boiler-code welding demands the highest quality levels and any process that has met these requirements has been accepted as a reliable industry tool. A number of manufacturers are investigating the use of carbon dioxide for their boiler-code weldments

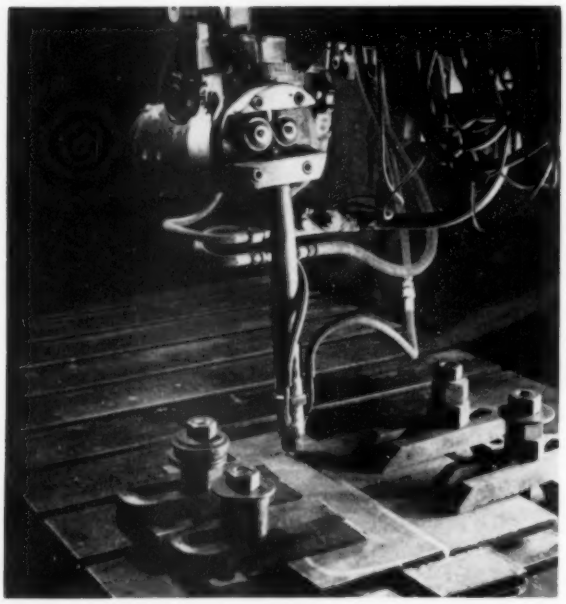

Fig. 2 Boiler-code test plates positioned for welding with an automatic carbon-dioxide gas-shielded welder

and some have already been approved. Inquiries have been received concerning this field of welding and it was due to this widespread interest that an investigation was undertaken to evaluate the weldability of unfired-pressure-vessel components using the carbon-dioxide process. These tests concern the welding of two grades of boiler-code steel, i.e., ASME type A285 grade C and type A212 grade B, since these are widely used in the manufacture of unfired pressure vessels.

This project was undertaken to determine whether the carbon-dioxide gas-shielded process would produce boiler-code-quality welds, and to ascertain optimum joint preparations and welding techniques. Considerable data has been obtained on the weldability of the thinner-gage mild steels (up to $^3/_8$ in. thick) and it was felt that $^1/_2$- and 1-in. thick material should be used for these tests. This would demonstrate the feasibility of multi-pass welding, and if these heavier thicknesses passed the weldability tests, it could be concluded that the thinner gages would also meet the requirements. The boiler-code steels show the same degree of weldability as other mild steels having the same chemistry and manufactured by similar methods.

Table 1—Chemical Analysis of Base Metal and Electrodes

	Base metal		Electrodes	
Element, %	A285 grade C	A212 grade B	A	B
Carbon	0.21	0.25	0.11	0.16
Manganese	0.43	0.77	0.92	1.14
Silicon	...	0.18	0.41	0.35
Aluminum	...	...	...	0.81
Phosphorus	0.015	0.013	0.016	0.020
Sulphur	0.032	0.028	0.021	0.016

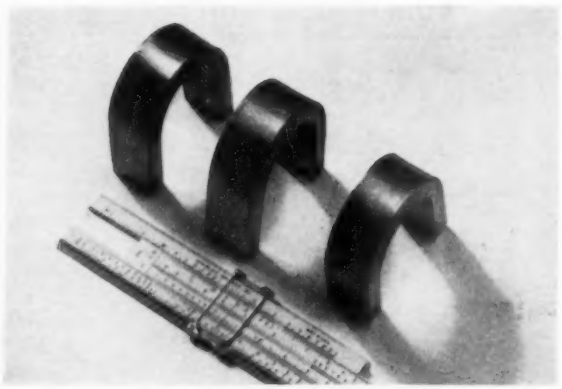

Fig. 3 Three bend-test specimens illustrating the high degree of ductility present in the boiler-code test plates. These specimens are from left to right: root bend, face bend and side bend

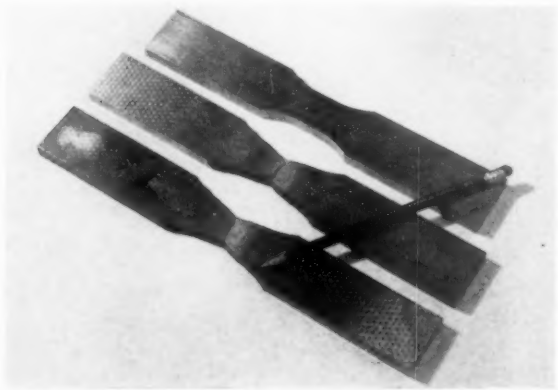

Fig. 4 Tensile-test bars machined from 1-in. boiler-code welder-qualification plates. Note the excellent ductility of the two broken bars

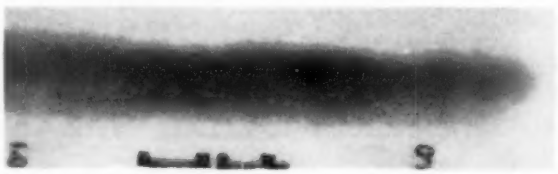

Fig. 5 A radiograph of a sound 1-in. butt weld on ASME grade A212 plate. This was a ten-pass weld, using type B electrode

The boiler-code steels differ in that they are rigidly held to specified mechanical and chemical limits by the steel mill. These limits are established by the ASME Boiler and Pressure Vessel Committees.

Electrode Composition Important

Two mild-steel electrodes were used in these tests and were representative of the two most readily available types for mild-steel applications. One was a silicon-killed type and the other a silicon and aluminum-killed electrode. Both electrodes contain manganese, and this element, together with the two deoxidizing elements mentioned above, remove free oxygen from the

weld metal and compensate for the base-metal dilution. The dilution of the weld metal by the base metal can cause the oxygen content of the weld to increase since most mild-steel base material is high in oxygen. The electrode must contain an excess of deoxidizing elements to combine with the oxygen and prevent porosity from this source. The analyses of the boiler-code base metal and electrodes are shown in Table 1. These are typical mild-steel compositions and it can be seen that the type A212 steel has been killed by the 0.18% silicon.

Welding-grade carbon dioxide was used for the shielding gas and the gas flow was maintained at 30–35 cu ft per hr. This grade of carbon dioxide is supplied by a number of distributors for the welding industry and is maintained at a low (-50° F) dew point.

Boiler-Code Test Procedures

The test plates were clamped rigidly to the welding table to obtain maximum restraint conditions. All plates contained surface scale typical of hot rolled steel and the edges were prepared by flame cutting. Figure 2 shows the automatic welding equipment used in these tests. Initial welds were of the single V, 60-deg included angle type, using a $^1/_4$-in. backing plate in accordance with the ASME boiler-code welder-qualification requirements (Section IX, Figure Q 23a). These welds were made with the semiautomatic (manual) equipment and consisted of five passes on one-half inch and ten passes on one inch material. The inter-pass temperature was held to 350° F maximum. The resultant guided bend, tensile, and radiographic tests showed the weld quality to be excellent and to meet the requirements of the code. Figures 3 and 4 show the excellent ductility and cleanliness of the guided bend and tensile bars following testing. The tensile fractures occurred in the weld metal with ultimate strengths of 70,000 to 75,000 psi, above the ASME specified minimum tensile strength for the A285 grade C and A212 grade B base metal.

All plates were radiographed and this, in combination with the mechanical tests, gave a reliable evaluation of weld quality. Figure 5 is a radiograph of a 1-in. A212 manual qualification weld. Note the soundness of the weld deposit which consisted of ten passes.

Edge Preparations Evaluated

Since carbon dioxide produces a deep, penetrating bead, a study was made to determine the optimum edge preparation for use with butt joints. Three single-V joints were prepared, having included angles of 30, 45 and 60 deg. These utilized back-up plates and were welded with varying techniques. When small stringer beads were used, severe center bead cracking occurred in the first or second pass. This could only be eliminated by utilizing a larger root opening ($^5/_{16}$ in. for 1-in. plate) and depositing excessive filler metal. Subsequent testing showed that the use of large high-deposition-rate beads eliminated cracking, permitted the use of edge preparations requiring less filler metal and reducing the number of passes per weld. The optimum edge preparation for a $^1/_2$-in. plate consisted of a 30-deg included angle, and for a 1 in. plate, a 45-deg included angle. Figure 6 shows a number of edge preparations and welding sequences that produced good quality welds.

High Current-Density Arc Required

In order to obtain a high degree of restraint, double-V joints were evaluated. It was also noted here that small stringer beads were unsatisfactory and frequently contained center-bead shrinkage cracks. By going to high-deposition-rate passes, it was possible to weld one inch material with only two passes—one on each side. Here the optimum edge preparation for one inch plate was a 45 deg included angle, a $^1/_8$-in. land, and a $^1/_{32}$-in. root opening. Future work may show that higher currents and deposition rates will permit the use of smaller included angles and root openings, and result in a greater saving of filler metal. It was the objective of these tests to take advantage of the deep penetration of the carbon-dioxide bead and keep to a minimum the amount of weld metal per joint. To increase the width of these beads, it was necessary to weld with a very high-current-density arc (287,000 amp per sq in.) and this was accomplished by reducing electrode diameter and increasing the wire-feed speed. When this was done, the weld metal washed into the base metal and solidified to form a wide bead having good penetration. The above current

BOILER CODE PROCESS DATA

WELD JOINTS	PASS	BASE METAL	ELECTRODE DIA. IN. TYPE	TRAVEL SPEED IN./MIN	AMPS	ARC VOLTS	DEP. RATE lbs./hr.	TEST RESULTS BEND	TENSILE	X-RAY
	1	A 285 TYPE	.045 A	AUTOMATIC 52	420	35	19.7			GOOD
	1	A285 TYPE	1/16 A	AUTOMATIC 44	500	34	24.8			GOOD
	1-2 3	A285	045 A	MANUAL 14	285 260	34 38	11.2 10.5			GOOD
	1	A212	.045 A	AUTOMATIC 10	450	43.5	20.8			GOOD
	1	A285	1/16 A	AUTOMATIC 11	600	46.5	25.6			GOOD
	1 EACH SIDE	A212	.045 A	AUTOMATIC 10-9	460 440	46.5 47	19.4			GOOD
	1 2 3	A212	1/16 A	AUTOMATIC 10 9 11	600 630 610	46.5 46.0 46.5	27.4			GOOD
	1 2-4 5-8 9-10	A212	1/16 B	MANUAL 7	290 300 325 300	36 33 33.5 33	8.8 13.0 14.4 13.0			GOOD

Fig. 6 Chart showing some recommended joint designs, electrodes and process data for welding ASME A285 and A212 boiler plate

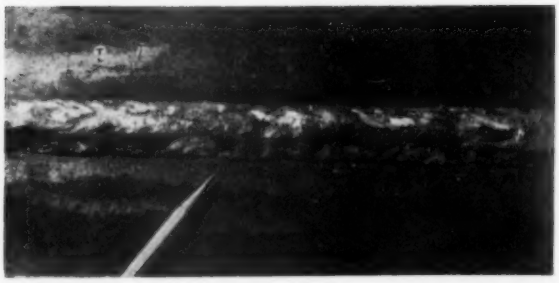

Fig. 7 A single-pass butt weld on $^1/_2$-in. plate made with an automatic welding machine showing the typical oxide film on the surface of a large carbon-dioxide shielded weld

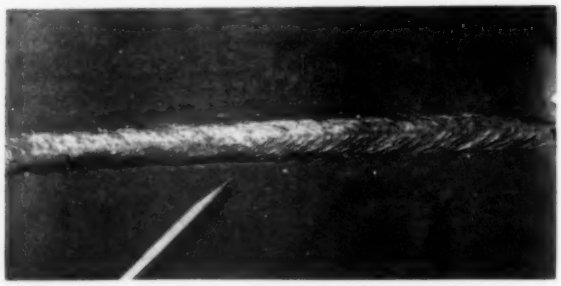

Fig. 8 A three-pass semiautomatic (manual) weld on $^1/_2$-in. A285 plate. This weld was sound and passed the ASME guided-bend, tensile and radiographic tests

density represents an 0.045-in. diam electrode welding at 450 amp.

All plates were welded in the flat position to obtain the highest travel speed. Also, the weld metal deposited at these high current densities was very fluid and solidified as much as $1^1/_2$ in. behind the arc. Because of this, it was considered desirable to start and stop each pass on a tab. This permitted the crater to solidify outside of the welded joint.

During cooling, the weld metal formed an oxide film which would partially flake off; Fig. 7 shows this condition on an automatic single-pass weld on $^1/_2$-in. plate. X-ray and macroscopic examinations showed that this film was superficial and not detrimental to weld quality. It was noted, however, that heavy scale from the base metal could cause oxide build-up and, on occasion, result in weld-metal porosity. Where this condition exists, it is recommended that an electrode of type B be used. The aluminum in this electrode is very effective in eliminating this type of porosity.

Weaving Technique Improves Quality

For semiautomatic (manual) welding, a weaving technique is recommended on all except the root pass. This permits the gases and oxides to escape to the surface, particularly those present on the surface of the previous bead. Figure 8 shows a three-pass manual weld on $^1/_2$-in. A285 plate. In automatic, higher current density welding, the larger, more active, molten pool effectively removes the gases and oxides. Figures 9 and 10 are cross sections of manual and automatic welds. Note the excellent bead shape and cleanliness of the weld beads.

This investigation has shown that quality welds can easily be made which meet the unfired-pressure-vessel code requirements. The boiler code does not grant a blanket approval for a welding process but requires a fabricator to qualify his individual welding procedure and operator. This is done under the supervision of a qualified boiler and pressure-vessel inspector.

It is felt there are a great number of unfired pressure-vessel applications which can be qualified for welding with carbon dioxide. Where this can be done, the advantages of this process—high deposition rates, no slag removal, visible joint while welding, and inexpensive shielding gas—can result in quality weldments and cost reductions for code welding.

Acknowledgment

The author wishes to thank John Lang, Lukenweld Div., Lukens Steel Co., for his assistance in the preparation of this paper.

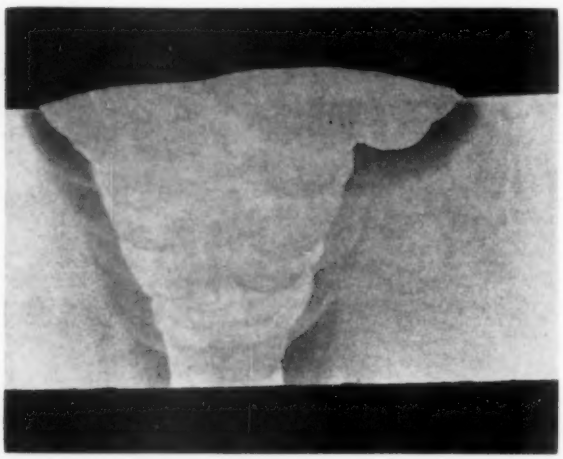

Fig. 9 A photomacrograph of a ten-pass semiautomatic (manual) butt weld on 1-in. plate illustrating the sound deposit obtained

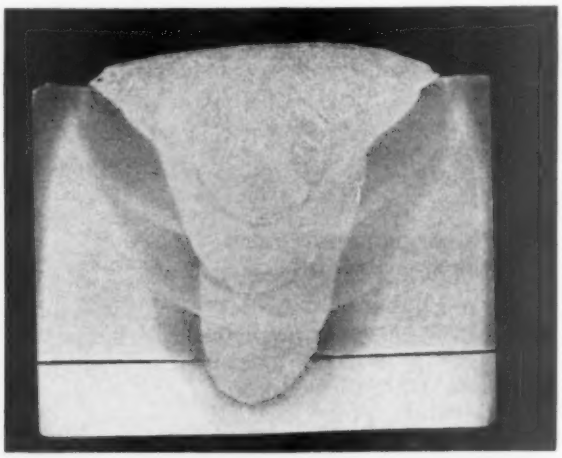

Fig. 10 A photomacrograph of a four-pass automatic butt weld on 1-in. plate. This is typical of the high-quality welds made on the A212 base material

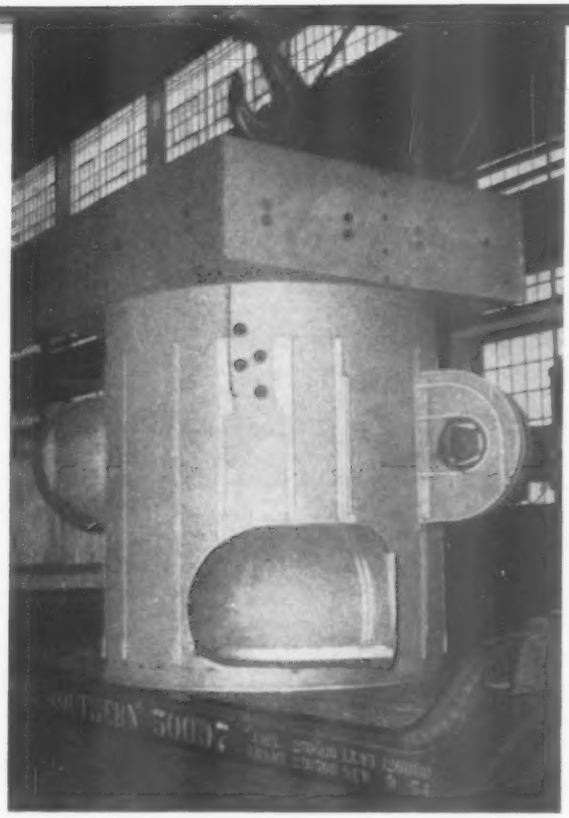

Fig. 1 Vessel being prepared for shipment

WELDING PROBLEMS IN PRESSURE VESSELS FOR NUCLEAR REACTORS

Paper presents information and data applicable to the fabrication of nuclear-reactor components, outlining the need for the most rigid quality control available to the present technology

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Presented at the 1957 AWS National Spring Meeting, Philadelphia, Pa., April 8–12.

SYNOPSIS. Pictorial representation of various reactor vessel and associated equipment and components is given. Detailed discussion of types of equipment, materials of reactor vessels and required physical properties is given. Data on impact properties of manual metal-arc and multilayer submerged-arc deposited metal is presented and discussion of manual metal-arc and submerged-arc stainless-steel cladding methods is presented. Design and nondestructive testing methods are briefly discussed.

Scope

The pressure vessels under discussion are the type containing the core structure in which nuclear heat is generated. These vessels, in turn, are surrounded by other containers for safety purposes and are connected to other type auxiliary equipment, some types of which are briefly mentioned.

All of the designs require close fitting of parts, such as thermal shields, flow baffles, core structures and the like, such that machining to very close tolerance is required. This also requires welding to very close tolerance, and specific heat treatments to insure dimensional stability for machining. Because of the large size of the parts of some reactor vessels, and reactor vessels themselves, special equipment for machining, jigging for welding and for control of tolerances is required. Design is such as to allow adequate nondestructive examination, and design must be such as to allow no crevices for corrosion, or stress concentrations, or stress corrosion, particularly where stainless-steel parts are involved. Because of high thermal stresses which can be set up for this type equipment, close attention must be paid to design for welding as regards differential properties of base materials in different directions and orientation of stress in fabrication and service.

Sodium Type

The first such vessels that the author's Company built were for use of sodium as the heat-transfer vehicle and were built of solid Type 304 and 347 stainless steel for subcontract for General Electric Company for equipment for the Atomic Energy Commission. The welding was standard except for complicated design and necessity of building and machining to close dimensional tolerance. Heat treatment of the welded structures was used extensively to maintain dimensional stability for close-tolerance machining. No fabrication difficulties were encountered except for base metal heat-affected zone stress-rupture cracking becoming evident after heat treatment for a few Type 347 stainless-steel plates which contained high residual stresses because of design and fabrication restraint conditions.

Figure 1 shows such a vessel on a railroad car being prepared for shipment. Figure 2 shows a portion of

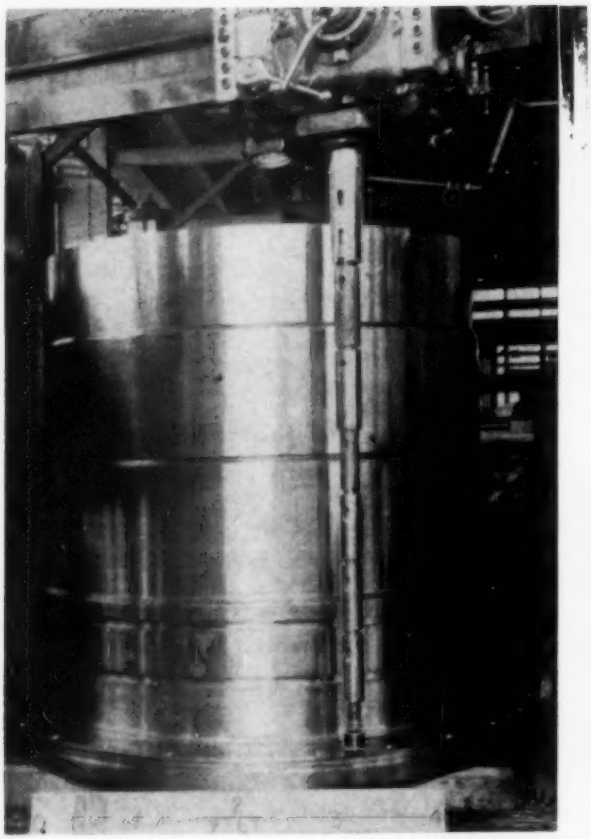


Fig. 2 Showing close-tolerance machining

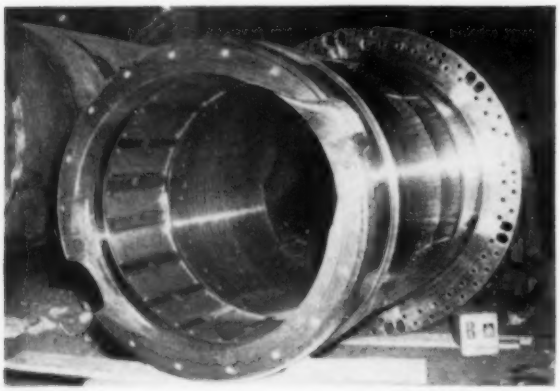


Fig. 3 Showing close-tolerance machining

this same vessel being machined. Note the finishes required. Figure 3 shows another portion of this vessel. Here the complexity of design and machining is apparent. Figure 4 shows another view of the internal structure. Extreme cleanliness is required in this type equipment and assembly is done in a controlled atmosphere "clean room."

Figure 5 shows a series of Type 347 stainless-steel nipples welded into a Type 347 shell of an auxiliary equipment to that mentioned above. Upon heat treatment of this weldment at 1850° F, stress-rupture crack-

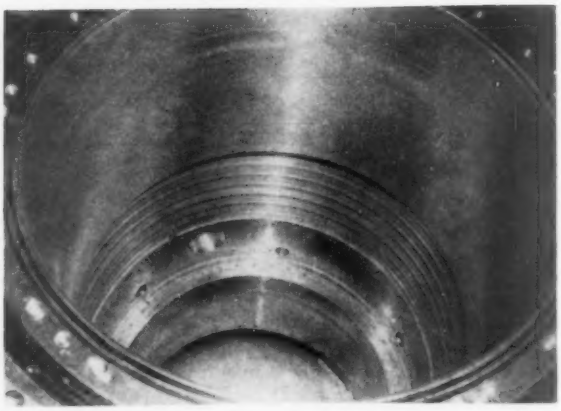


Fig. 4 Showing close-tolerance machining

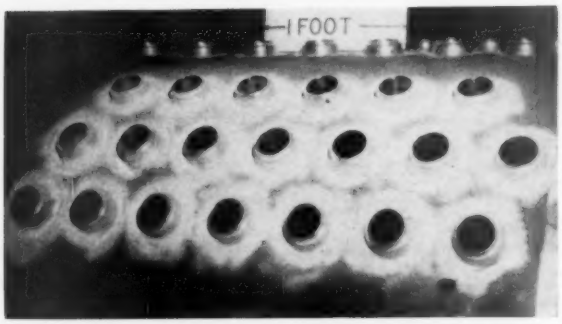


Fig. 5 Type 347 nipples welded into Type 347 shell

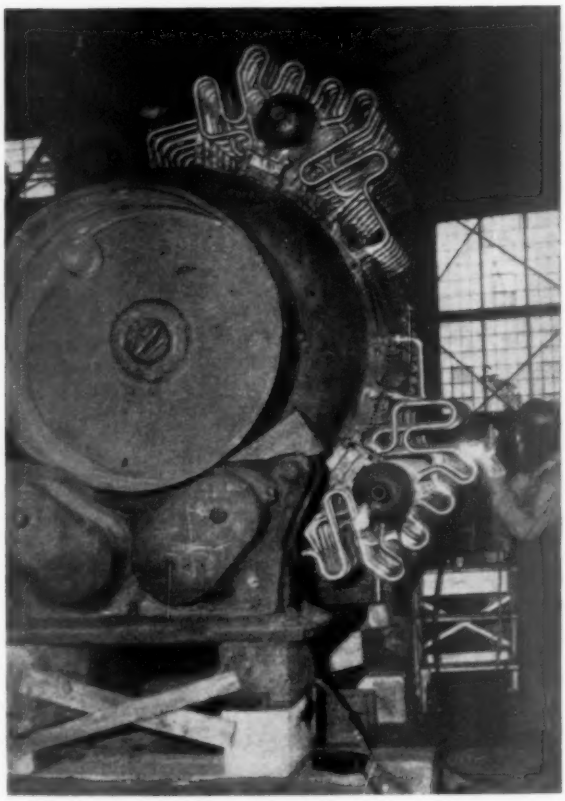


Fig. 6 Completed vessel of Fig. 5

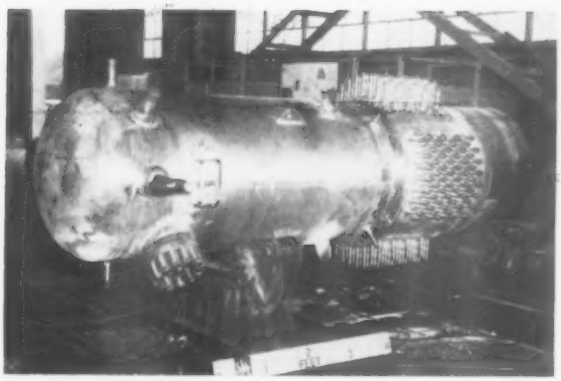


Fig. 7 Type 304 auxiliary vessels

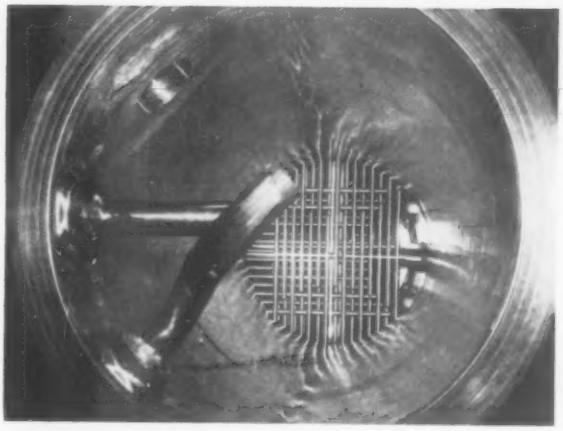


Fig. 8 Another view of vessel shown in Fig. 7

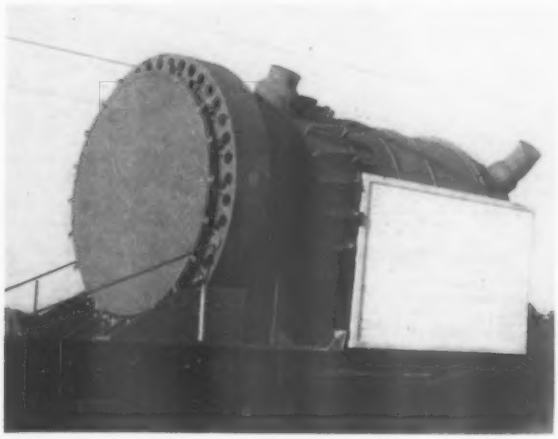


Fig. 9 Pressurized-water reactor being shipped

ing of the shell plate material adjacent to the welds occurred. These cracks were removed and one-half of the nipples rewelded, skipping alternate nipples, the vessel heat treated, and the remaining nipples then welded and the vessel again heat treated. With this procedure, no difficulty resulted. The base material was Nos. 2 to 5 grain size and is not expected to stress-rupture crack except when subjected to excessively high biaxial residual stresses. Figure 6 shows an over-all view of the substantially completed part.

Fig. 10 Pressurized-water reactor in fabricating shop

Pressurized-Water Type

Figure 7 shows another type auxiliary vessel for a pressurized-water type reactor for subcontract for Westinghouse Electric Corp. for equipment for the Atomic Energy Commission. This vessel is made of Type 304 stainless steel and contains numerous heating elements near one end. Figure 8 is a view looking into one end just prior to attachment of a head in a "clean room." The attachment of the head was done with inert-gas first passed in order to maintain the cleanliness required.

Figure 9 shows the main vessel of a pressurized-water reactor being shipped. This equipment is to operate at 2500-psi pressure and approximately 600° F. Because of the large size of the equipment and the desire to build of ASME Code materials, SA-302 B material was chosen to be used. This steel has a minimum tensile strength of 80,000 psi and its use resulted in a design wall thickness of approximately $8^1/_4$ in. The design also required that all surfaces in contact with the pressurized water be clad with stainless-steel Type 304 extra-low-carbon material. The design also required a bolted cover for opening and closing the vessel. This necessitated the use of extremely large ring forgings for the flanges. These forgings were made of essentially the same analysis as the plate material.

The plate, up to $8^1/_4$-in. thickness, was bought as a commercial clad material with cladding integrally bonded to the backing steel. The forgings were clad by deposited weld metal as were the nozzles which were fabricated from plate, and plate over $8^1/_4$-in. thickness.

Figure 10 is another view of the vessel in the fabri-

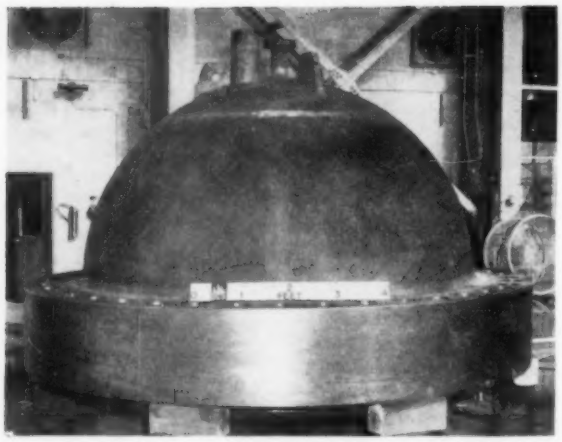


Fig. 11 Hydrostatic-test head of vessel shown in Fig. 10

Fig. 12 Operation head of vessel shown in Fig. 10

cating shop. Figure 11 shows a hydrostatic-test head. The construction consists of a large ring forging, four torus head segments formed from plate and a dome section. The welds are all 10-in. thickness in 10-in. thick plate. Figure 12 shows the operation head, which was made in the same manner as the hydrostatic test head but which has numerous penetrations. The welds of nozzles to operation head are "through" welds with the welds through the nozzle walls and approximately 2-in. deep across the plate thickness. The center "O" pattern of operation head penetrations is solid weld metal in which the weld is keyed into the thickness of the head plate approximately 2 in. through its thickness. This weld was examined by both radiography when partially built up and by ultrasonic testing then and upon completion. It was free of defects.

All welds are "through" welds, containing no design notches. Figure 13 shows design of standard butt weld —in this case the weld between the shell and the bottom head. Figure 14 shows design of shell nozzle welds. In these cases the weld thickness is approximately 10 in. The cover head plate thickness at the butt welds is also 10 in.

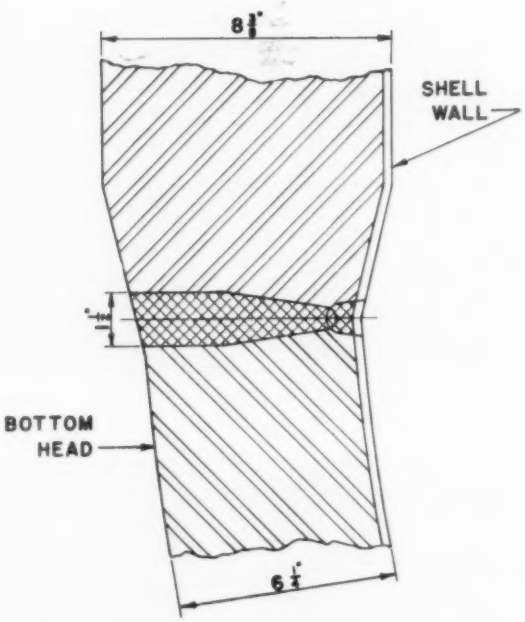


Fig. 13 Typical butt-weld groove

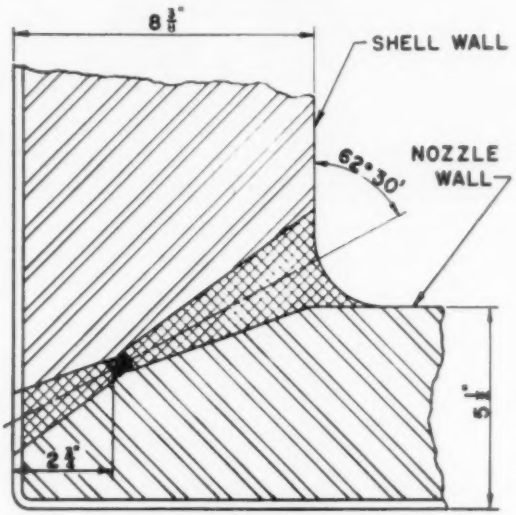


Fig. 14 Typical nozzle-to-shell weld groove

Material

The portions of nuclear component vessels made from ferritic steels, mentioned above, are made from base material having the chemical analyses and physical properties given in Table 1.

Because of past occurrence of brittle fractures in welded structures, close attention has been given to the development of and use of materials which exhibit low "nil-ductility" and Charpy V-notch impact transition temperature. For the materials chosen, the impact requirements generally necessitate use of accelerated cooling from the austenitizing temperature, followed by tempering. For the thinner thickness, normalizing, followed by tempering, results in adequate impact properties.

Table I—Chemical Analysis, %

	C	*Mn*	*Si*	*P, max.*	*S, max.*	*Mo*	*Ni, max.*
Plate	0.20–0.27*	1.10–1.50	0.15–0.30	0.035	0.040	0.40–0.60	0.80
Forgings	0.15–0.27	1.20–1.50	0.15–0.30	0.03	0.03	0.45–0.60	0.40–0.70

Physical Properties

Tensile strength, psi	80,000–100,000
Minimum yield, psi.	50,000
Minimum elongation in 2 inches, %	17
Minimum reduction in area, %	35

* Dependent upon thickness.

Plate: 30 ft-lb Charpy V-notch impact at $\frac{1}{4}$-in. thickness level at +10° F.

Forgings: Aim for 30 ft-lb Charpy V-notch impact at finished machined highly stressed surface at +10° F.

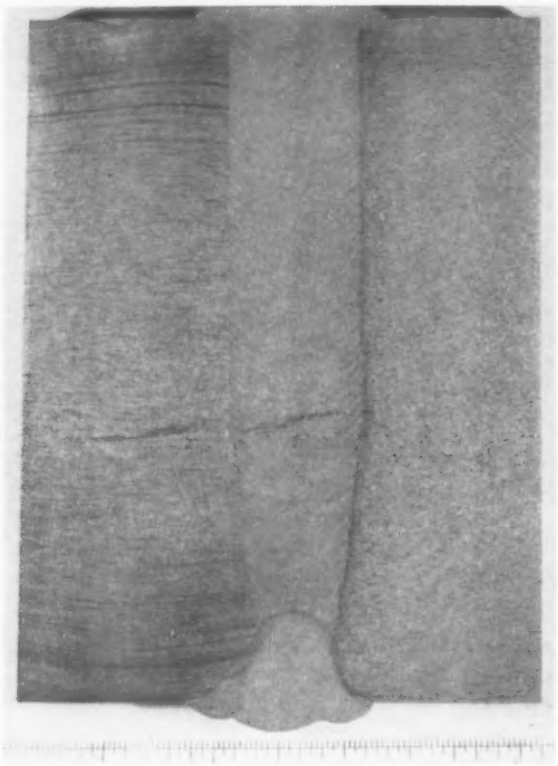


Fig. 15 Cross section of multilayer submerged-arc weld between 8-in. thick forging and 8-in. thick plate

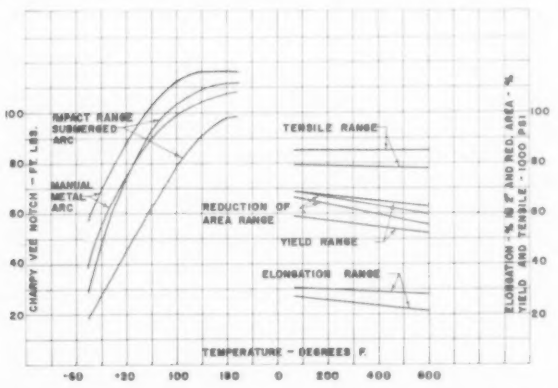

IMPACT RANGE SUBMERGED ARC
MANUAL METAL ARC
TENSILE RANGE
REDUCTION OF AREA RANGE
YIELD RANGE
ELONGATION RANGE
CHARPY VEE NOTCH - FT. LBS.
ELONGATION - % IN 2" AND RED. AREA - % YIELD AND TENSILE - 1000 PSI
TEMPERATURE - DEGREES F.

Fig. 16 Physical properties of multilayer weld metal heat treated at 1150° F for 24 hr, furnace cooled. Nominal analysis: 0.1 C, 1.7 Mn, 0.5 Mo. Lime-base flux

The properties must be met on the finished product, which has been given several fabrication heat treatments. The same properties must be met in the weld metal and heat-affected zones, all handled exactly as the job as regards heat treatment and all fabrication procedures.

Meeting the above properties in plate up to 10-in. thickness has been accomplished. Needless to say, however, it has been more difficult meeting them in the extremely large forgings and it has been necessary to determine the temperatures at which 30 ft-lb is obtained and these temperatures used in setting hydrostatic test temperatures and operational heat-up rates. Meeting the above properties in weld metal and heat-affected zones has been readily accomplished for either manual metal-arc welding or multilayer submerged-arc welding.

Figure 15 shows cross section of a test plate of an 8-in. thickness forging welded to a 8-in. thickness plate by multilayer submerged-arc welding.

Figure 16 shows range of all-weld-metal physical properties obtained on many tests after standardization of welding procedures. Figure 17 shows range of all-weld-metal physical properties obtained with various analyses of weld metal while experimenting to settle upon welding procedures.

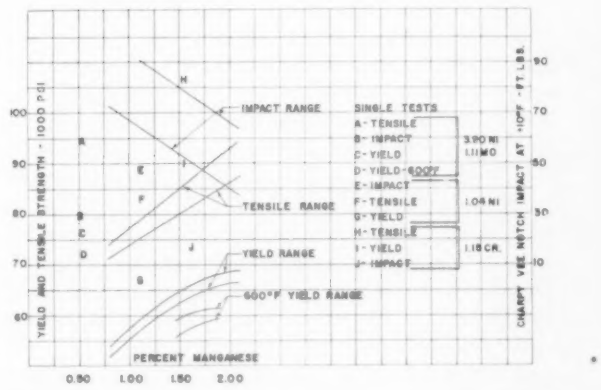


Fig. 17 Physical properties of multilayer submerged-arc deposited metal heat treated at 1150° F for 24 hr, furnace cooled. 0.07 to 0.1 C, 0.32 to 0.54 Si, 0.01 to 0.023 S and P, 0.46 to 0.59 Mo

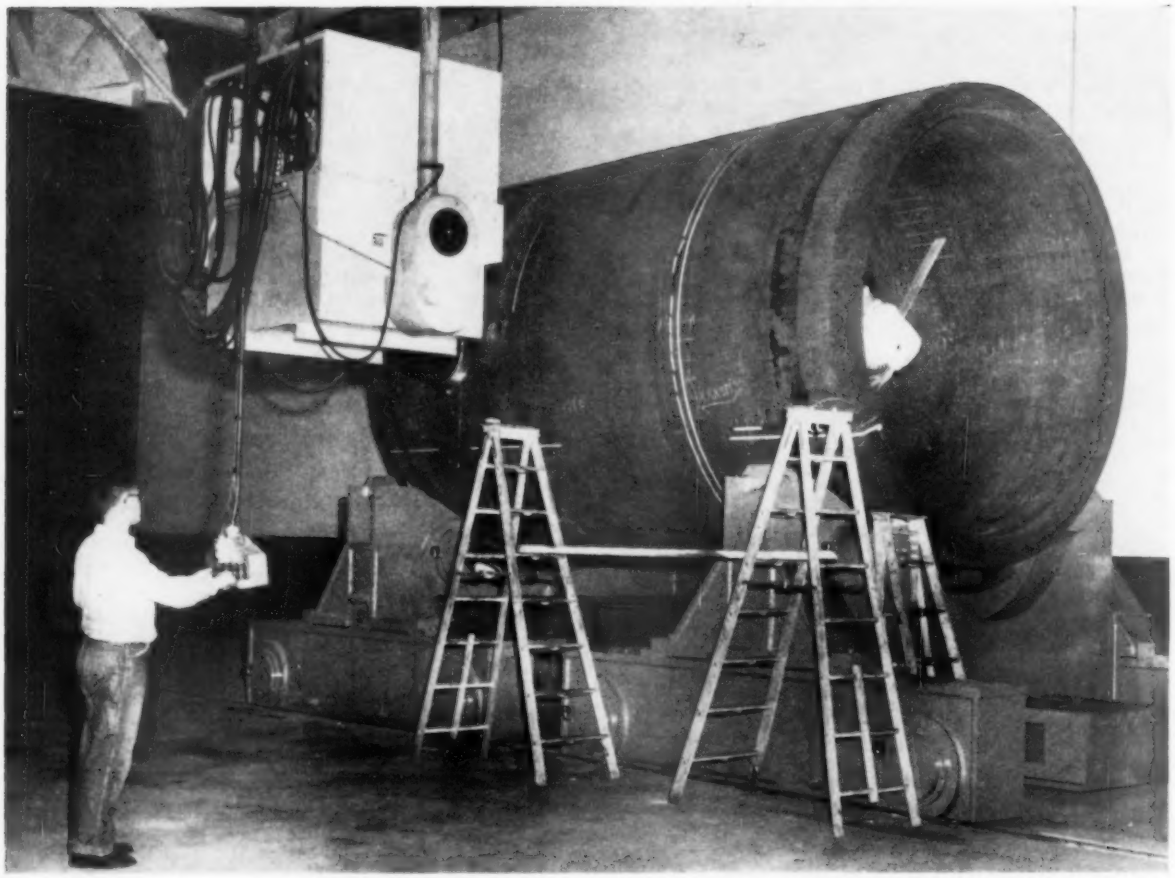


Fig. 18 Equipment for heavy-thickness radiographs

Nondestructive Testing

Because of critical safety requirements necessary for nuclear reactors, their fabrication is subject to the most rigid quality control available to the present technology. The welds in extremely heavy thicknesses—up to 10-in. thick as mentioned in this paper and up to 14-in. thick as presently in process—require special high-voltage equipment for radiography. Figure 18 shows the type of equipment used for this purpose. This equipment allows the examination of thicknesses up to 20 in. and is extremely sensitive in the thickness range over 4 in. The outline of a penetrameter of thickness of $^1/_2$ of 1% of the thickness being radiographed is readily seen. Soundness requirements consist of meeting radiographic standards somewhat stricter than ASME on some work. On USN work, the requirement presently consists of meeting a single film standard (originally developed for high-pressure piping) up to 6-in. thick (which has a slag line up to $^1/_8$-in. long allowed), and this same film regardless of thickness above this except that a slag line up to $^3/_8$-in. long is allowed provided it has no "fangs" and is separated by 6 in. from another slag line. The amount of porosity allowed is extremely small.

The base material is subject to ultrasonic-test requirements and the finished parts subject all over to magnetic-particle examination on ferritic steels and penetrant-oil examination on austenitic steels.

Cladding

Internal reactor circuits require surfaces which must be fabricated to extreme cleanliness, and which will not corrode and form contaminants which will become radioactive in service. Such surfaces require the use of solid stainless steels or the cladding of low-alloy steels with a noncorrodible material.

The commercial rolled-clad plate forms a continuous rolled bond which, however, is checked over by ultrasonic method and repaired if required. Areas which cannot be clad in this manner are clad either by the manual metal-arc method or by the series-arc submerged-arc method. Figure 19 shows a component after cladding by the latter method with Type 308 metal and prior to being machined. Specifications originally required a maximum carbon content of 0.06%. This has been recently raised to 0.08%. Figure 20 shows chemical analysis determined at various levels through the thickness of such a cladding which has been given two different heat treatments, one simulating cladding of a formed part which is subsequently given only fabrication stress-relieving heat

Fig. 19 Dome portion of pressurized-water-reactor head immediately after series-arc submerged-arc cladding

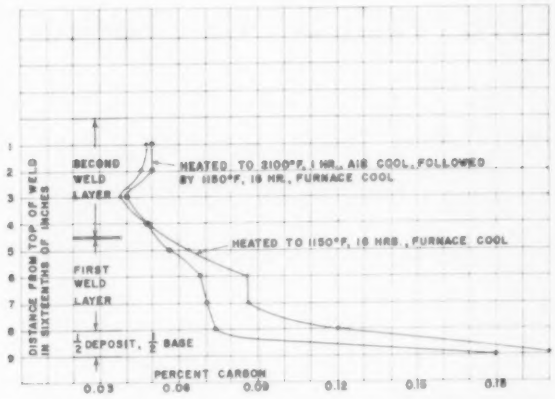


Fig. 20 Carbon analysis through thickness of two-layer weld cladding of austenitic stainless steel deposited on carbon-steel base plate by series-arc submerged-arc process

treatments and the other simulating a cladding in the flat followed by a hot-forming operation such as hot pressing a head and this followed by fabrication stress-relieving heat treatments. Note that the maximum carbon content requirement is readily met. Method of obtaining millings for analysis is shown in Figure 21.

General

Internal and external associated structures require the welding of numerous other materials and combinations of materials such as Inconel, Inconel "X," precipitation-hardening stainless steels, wrought iron, aluminum and a variety of other materials. Discussion of these procedures is beyond the scope of this paper. For reactor vessels, there is a trend toward use of higher-strength materials allowing lighter-weight structures. The use of quenched-and-tempered steels for this purpose will probably increase.

Acknowledgment

Credit for development of information listed above is due to the writer's associates, E. C. Chapman, director of Metallurgical Division, C. T. Ward, L. N. Wall, C. R. Pandelis and R. D. Brown. Major credit is due to all the members of the Nuclear Components Design and Fabrication Division.

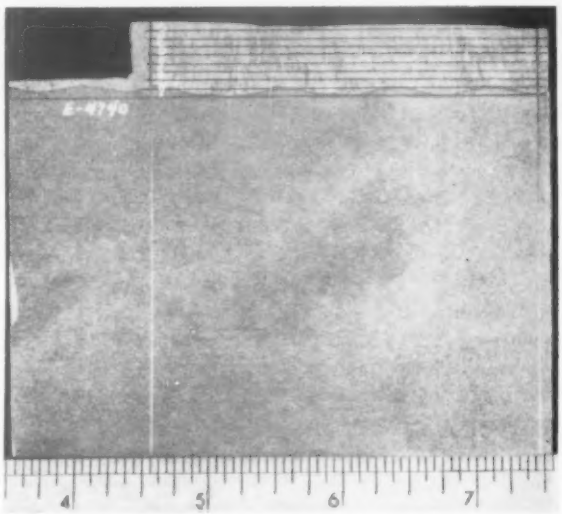


Fig. 21 Method of obtaining millings for chemical analysis results shown in Fig. 20

THE WELDING QUALIFICATION PROBLEM

Report by a special committee of TAC emphasizes that the basic factors in the application of welding constitute the only sound basis for standardization of a method for welding qualification

INTRODUCTION

The problem of establishing a flexible and generally applicable method for the qualification of welding in any type of application has long confronted the AMERICAN WELDING SOCIETY. Several attempts have been made in the past to resolve this problem without success and many suggestions of limited scope have been offered, most of which further confused the points at issue. Over the past two years a Special Committee (Qualification Task Force), appointed by the AWS Technical Activities Committee, has been actively engaged in exploring the various phases of this problem with the object of establishing some sound basis for a general qualification method. This treatise presents the results of this activity, together with an explanation of the thinking behind the concepts presented.

Fundamentally, the basic objective of any welding application is to obtain a weldment which will be adequately serviceable for the purpose for which it was designed and fabricated. There should be no disagreement on this point from any angle of interest. It is in regard to the mechanism by which the application is accomplished that disagreements arise. The AMERICAN WELDING SOCIETY hopes to facilitate the resolution of such disagreements by promoting recognition of the importance of all factors involved in the application of welding.

In all of its deliberations the Special Committee has been guided by the principles enunciated at the Kansas City Symposium of June 1955, as sponsored by the Technical Activities Committee and published in THE WELDING JOURNAL of August 1955. These are to the effect that requirements for welding qualification should be based upon the severity of the service conditions for the weldment and that proper consideration should be given to "all factors involved in the application of welding."

In any application of welding it is considered by the Committee that there are at least two interests involved and, in some cases, a third interest may be concerned with the results produced, particularly with reference to the service usage thereof. These three groups are as follows:

(a) The Producer or Fabricator.
(b) The Purchaser or User.
(c) The Code Writing or Regulatory Body.

(a) *The Producer or Fabricator.* This may be a company making a product which is a weldment or includes weldments. It may be a fabricator who produces weldments for use in a product or for some other company's use. Whether it is a large or small company or an individual, anyone producing weldments must know what the service requirements are for each joint involved or have the requirements prescribed in advance of fabrication.

(b) *The Purchaser or User.* This may be a company or an individual who must specify the service requirements for the weldment or procure the weldment from someone who knows the requirements and either has made the weldment or has had it made accordingly, if he, the Purchaser or User, expects to be satisfied with the performance of the weldment.

(c) *Code Writing or Regulatory Body.* This is an organization which attempts to protect the Purchaser by prescribing rules of performance to obtain assurance that the product will reasonably meet the prescribed service requirements.

After considering the welding qualification problem from all angles and various practical viewpoints, including a variety of service conditions and welding processes, the Committee came to realize that welding qualification cannot be treated as a separate individual entity alone by itself, isolated from all the other factors involved in welding application. It is but one of several factors, each influenced to some extent by the others. This relative influence varies with the nature of the welding application and the welding process involved.

Proceeding in this vein, with thorough and exhaustive deliberation, the Committee has finally rejected the philosophy of "Qualification Above All" as a workable basis for standardization. Instead, the basic factors of any welding application are emphasized for general recognition as the only sound basis for standardization of a method for welding qualification.

A PROPOSAL—

BASIC FACTORS IN THE APPLICATION OF WELDING

FOREWORD. In the successful application of any process, certain factors must be considered. This proposal presents the basic factors to be used as a guide in all applications of welding. Each of the factors should be considered for the simplest weldment, such as an ash can, as well as the most complex weldment. *This proposal is not a standard nor should it be used as such.*

General

In the fabrication of any weldment it is essential that adequate attention be given to each of the following factors which are discussed in detail in subsequent paragraphs.

1. Service Conditions (under which the weldment will be used).
2. Materials (base metals and welding materials suitable).
3. Design (size and shape of members and joints involved).
4. Joint Welding Procedures (to be used in fabrication).
5. Welding Sequence (consecutive order of welding joints).
6. Qualification (demonstration of applicability by fabricator).
7. Supervision (control of fabrication operations).
8. Inspection (examination for compliance with requirements).

1. Service Conditions

The specific service conditions which must be met by the weldment and all joints thereof should be evaluated for the purpose of obtaining the necessary design, fabrication and inspection information. A listing of types of service conditions is shown in Table 1.

2. Materials

The capability of the base metals and the welding materials designated, for use in producing joints adequate for the designated service conditions, should be determined. This may be done by reference to appropriate technical data or may be derived from appropriate development tests.

Table 1

Service loading	*Service temperature*	*Service properties*
A. No significant stress	1. Normal	a. Leak tightness (gas, oil, water, etc.)
B. Static	2. High	b. Thermal conductivity
C. Fatigue	3. Low	c. Electrical conductivity
D. Impact		d. Corrosion
E. Thermal shock		e. Wear
		f. Appearance

The base metals and welding materials selected for use in fabricating the weldment should be identified by reference to standard specifications, recognized industrial standards or by other positive means. In addition, the condition of the base metals should be designated i.e., whether cold rolled, normalized, annealed, quenched and tempered, etc. (The thermal treatment after fabrication should also be specified).

3. Design

The design should be such that the weldment will meet the service requirements. Drawings should be prepared to show the shape and over-all dimensions of the weldment. In addition, written general requirements and instructions should be provided as may be necessary for the design and fabrication of the weldment.

The design of the weldment should include details of each joint to be welded, shown by the AWS Standard Welding Symbols, implemented by such drawn details and written instructions as may be necessary for proper fabrication.

4. Joint Welding Procedures

The welding of all joints of a weldment should be covered by written joint welding procedures.

Each written joint welding procedure should include all details and information necessary for properly welding the joint or joints to which it applies.

5. Welding Sequence

When necessary, the order in which the various joints in the weldment are welded should be established.

6. Qualification

Joint welding procedures should be qualified by the preparation of "workmanship" specimens and, where applicable, other test specimens prepared using the joint welding procedures prescribed for the fabrication. These specimens may be a complete production item or portions thereof, or a series of weld joint specimens representative of the joints in the weldment. The extent of qualification testing should be correlated with the service requirements.

In fabricating the weldment by machine or automatic welding, only qualified or approved equipment should be used.

Welding personnel should demonstrate that each individually has the ability to produce sound welds using the materials and welding procedures to be used in fabricating the weldment.

7. Supervision

Supervision of welding operations should be provided to assure that the specified joint welding procedures are being followed and that all other requirements

prescribed herein, as well as those of the applicable code or fabrication specification, are being met.

8. Inspection

Inspection for maintaining the quality of materials and fabrication of the weldment should be provided.

The quality level and inspection methods should be only so rigid as required to meet service requirements but should not be so low as to condone poor workmanship.

DISCUSSION

1. Service Conditions

A basic principle of application engineering is that the service conditions, under which the weldment is to be used and for which the weldment must be serviceable, dictate the requirements for size, shape, materials and design of the weldment. By some it may be considered that all of these are included under the one item of design but such is of minor importance at the moment. The important point is that service conditions are the guiding factor for the design and fabrication of the weldment.

With reference to the point that service conditions should dictate the requirements for welding qualifications, it appears that very little progress can be made in establishing applicable rules for welding qualification unless some method can be found for specifying types of service conditions for which weldments are designed and fabricated. This is a fundamental and complex problem but the Committee has proposed a method such as is illustrated by Table 1 of the Proposal.

This method predicates the type of service on three basic conditions: (1) type of loading, (2) service temperature and (3) service properties required, since these appear to be fundamental to any type of service.

2. Materials

Materials suitable for the weldment fabrication must be selected at some point in the fabrication planning. Just when this is done is not so important as is the fact that it is done only after due consideration of pertinent material data and data from adequate welding engineering research and development testing. Some prior knowledge and experience with the fabricability and weldability of the selected materials is essential to successful fabrication. Welding qualification should not be the last resort, the crutch to lean on for such data. The development of a proper materials engineering background requires a much broader scope of testing than is afforded by the usual qualification testing procedures. These considerations are important to successful welding application.

3. Design

For some types of weldment it may be desirable that a general layout, shapewise and dimensionwise, be prepared. For other types of weldment, possibly of less complex nature, such a layout may be unnecessary. Where used, a general layout affords a proper basis for beginning a "meeting of the minds" between the user and producer interests, as well as the code interest when involved, prior to design and fabrication. It is a proper step in the mechanism of welding application, wherever and whenever it can serve a useful purpose.

The designing of a weldment is an essential step in planning the production of the weldment. It cannot very well be omitted and at the same time accomplish adequate understanding by any production organization of what is desired as a serviceable weldment. In accomplishing any weldment design the details usually should be arrived at by consideration of the service requirements, materials selected and the probable welding process to be used in fabrication.

When the design is accomplished without regard for the welding characteristics of the base metal or the general characteristics of the welding process to be used, either the production costs are increased unduly or the design must be revised with costly delays in production schedules. Careful consideration of this factor is an essential need in successful application planning.

4. Joint Welding Procedures

Any welded joint is produced by using some specific joint welding procedure. This fact is inescapable. Whether or not the exact procedure has been written down somewhere as a matter of record is beside the point, at the moment, for the mere fact that a welded joint has been produced is clear evidence that some specific joint welding procedure was used to produce it. This is true of any welded joint.

The properties of a welded joint are mainly dependent upon the joint welding procedure used in welding it. It is therefore important that the procedure be chosen carefully and with due understanding of the effects of the various factors involved. This is not something which one can "pick out of a hat" like a magician. Some prior experience is necessary and this is an important factor in welding application.

Since the production of a weldment may involve any number of joints to be welded, possibly of different types and forms, a number of joint welding procedures of some difference may be required. In such a situation it is usually desirable that these several joint welding procedures be recorded so that all personnel concerned with the welding may understand clearly just what is to be done. Such a record is of value not only to supervisory personnel but also to those who are responsible for enforcement of pertinent quality control measures.

5. Welding Sequence

When fabricating a weldment which involves the welding of more than one joint, the joints cannot all be welded simultaneously except perhaps in rare instances when using a machine welding process. Since the joints of the weldment usually are welded individually, they must be completed in some order of sequence which is known as "welding sequence."

Often this "welding sequence" is of minor consequence and yet there are often instances where a successfully economic fabrication of the weldment dimensionwise is vitally dependent upon welding sequence. In such cases a careful determination and record of proper sequence for welding the joints is essential to guide a successful fabrication. The proper sequence may be indicated by written instructions, or where desirable, by information given on the drawings.

6. Qualification

If one were to ask a dozen individuals "What is the purpose of welding qualification and of what should it consist?" it is quite probable that he would get a dozen different answers. It is also probable that some different opinions would be found as to the concept of "What is qualification?" and "What is its significance?" In view of this situation it is evident that the latter question must be resolved in some way before any progress can be made in answering the former.

Basically, qualification is essentially a demonstration of capability. This demonstration includes both the act of doing something and an evaluation of the results of that act. This evaluation must be made within the limitations of whatever conditions may have been imposed for the demonstration. Having accomplished the qualification, one must understand that the capability demonstrated thereby is neither a guarantee of future behavior nor a dependable indication of future functioning of the human mind, for such is beyond the realm of qualification.

The problem of deciding what is appropriate for welding qualification has existed ever since the first use of welding as an industrial fabrication process. In the past, qualification has been given the greatest emphasis in exercising control of fabrication and this situation has existed mainly due to lack of appreciation for the other factors involved in producing a weldment. Also the requirements for qualification have never recognized that a considerable difference in service requirements exists between an ash can and a pressure vessel. Consequently, the qualification often imposed was too severe in the one case and not searching enough in the other.

In the early days, when authentic welding engineering data were not generally available, qualification for each job emphasized complete coverage of procedure and personnel, by various joint property tests, to establish potentialities since, at that time, welding was regarded with considerable skepticism as a fabrication tool.

Since the philosophy of "qualification above all" was found to be effective as a brake on an unbounded enthusiasm for the promiscuous use of welding in applications with service conditions of some severity, qualification naturally came to be applied indiscriminately to welding applications where a lesser severity or no appreciable severity of service conditions existed. Thus, for the latter, the requirements for welding qualification became a serious economic problem, as well as a problem of compliance, such that welding qualification came to be regarded as a hurdle to be avoided wherever and whenever possible. Often this attitude resulted in no effective quality control at all, which is admittedly undesirable.

Considering the present status of welding engineering development, the Committee recognizes that "qualification just for the sake of qualification" is an obsolete philosophy. However, it recognizes that qualification for a specific welding application often serves as a very effective device for screening unknown potentialities. And yet, where an adequate background of welding engineering experience and data have been accumulated by a fabricator, any extensive and elaborate qualification testing serves no useful purpose except perhaps to eliminate some doubts from the customer's mind or strengthen a wavering faith. In any case of this sort, the time and cost are not justifiable.

The Committee has a firm belief that the simplest and most effective manner in which the capability for welding fabrication can be demonstrated, to the satisfaction of the customer or user, is for the fabricator to make up a "workmanship" or "appearance" sample of the work which he is expected to do so that the customer may have some tangible evidence of what he should expect from the fabricator's work. Such a sample may be a regular production item, a suitable portion or portions thereof or special samples of such nature and number as to show what certain or all of the welded joints in the weldment may be expected to look like.

Such a demonstration of potentiality should be adequate as qualification for many welding applications where the service conditions have minimum or no particular severity. This procedure should be adequate where the fabricator has had no extensive welding engineering background, since the workmanship sample can be subjected to such destructive testing as may determine joint properties pertinent to the particular welding application involved.

Where the service conditions are of appreciable severity, the Committee considers that some destructive testing, in addition to the workmanship sample, may be desirable. However, the amount of such testing should be the minimum sufficient to show the performance level of the selected joint welding procedures. In those cases where the fabricator can show an adequate welding engineering background with prior experience in welding application similar to the one in hand, this destructive testing may not be required and the workmanship sample would be considered sufficient for qualification. However, in order to

apply this principle fairly and effectively, some yardstick is needed by which to evaluate properly any welding engineering background and fabrication experience.

The problem of establishing rules for determining the type and amount of qualification testing required, in situations as outlined above, is concerned somewhat with the yardstick used in evaluating welding engineering background and fabrication experience. The Committee has not attempted other than to suggest the workmanship sample as a basic requirement for welding qualification.

7. Supervision

Any emphasis on qualification as the major element of welding quality control, to the subordination or exclusion of supervision and inspection, is a policy which the Committee most emphatically condemns since such a policy is based upon the presumption that qualification is both the beginning and the end of welding quality control. Nothing is further from the truth. None of the basic factors listed in the Proposal can be substituted for any of the others in any well organized production setup.

One may have the most perfect weldment design, properly selected materials and procedures and a fully qualified production organization but, if all the details of pertinent production operations are not performed properly, the results will not be all that should be expected. The Committee proposes recognition of the importance of proper supervision of production operations in any welding application.

8. Inspection

It is a fundamental fact that the final quality of a piece of work cannot be accurately judged until the work is completed. The basic function of inspection is to determine whether the results of fabrication comply with the quality requirements prescribed for the welding application. In the fabrication of weldments the nature and the extent of inspection of the finished work is conditioned upon how adequately the fabrication operations are supervised and inspected during production. The method of manufacture and the prescribed quality requirements may dictate inspection at certain stages of manufacture in order to accomplish an effective quality control.

In any specific case, all three interests, as referred to previously, have a responsibility in inspection to insure that each product produced meets the quality requirements dictated by the intended usage.

WORK TO BE DONE

This Proposal by the Committee is a statement of basic factors and the basic principles concerning them for general consideration as a guide for operation in applying welding qualification to industrial fabrication. The Proposal is incomplete in three respects and it is in regard to these three areas that constructive suggestions are solicited.

One area lies in the field of materials and engineering development which is No. 2 of the Proposal. It relates to the establishment of a yardstick for evaluating the adequacy of welding engineering background and fabrication experience for the purpose of determining the nature and extent of destructive testing necessary for qualification in any specific welding application. Such a yardstick must include consideration of the minimum properties required for the type of service intended for the weldment, together with appropriate allowances for prior engineering background and fabrication experience of the fabricator.

With reference to joint welding procedures, which is No. 4 of the Proposal, the Committee suggests that standard forms for recording these procedures be used but drafts of such forms have not been attempted. It is considered that these standard forms may be different for various welding processes. However, it is thought that the factors of joint welding procedure for any welding process may be included under six general headings as follows:

1. Base Metal
2. Joint Design
3. Joint Preparation
4. Welding Materials.
5. Welding Conditions.
6. Post-Weld Treatment.

With regard to qualification, which is No. 6 of the Proposal, the Committee has not indicated just what standard weld-joint soundness tests may be used for qualifying welding personnel. Neither are the standard forms of destructive tests for weld-joint properties indicated because the nature and extent of such tests which may be used in any specific welding application will depend largely upon the yardstick for evaluating background previously referred to.

The Committee is hoping to obtain constructive suggestions on the above proposal. Address all communications to Technical Secretary, American Welding Society, 33 West 39 St., New York 18, N. Y.

CONSUMABLE-ELECTRODE INERT-GAS WELDING WITH SMALL-DIAMETER WIRES

Work to date indicates that process is capable of producing excellent-quality welds in thin-gage materials at high welding speeds

BY K. E. RICHTER AND J. F. M. ESSIG

INTRODUCTION. As originally conceived about eight years ago, consumable-electrode inert-gas welding was largely limited to 12-gage or thicker materials, using $^{3}/_{64}$ or $^{1}/_{16}$-in. diam welding wire. Shortly after its inception, separate investigations were undertaken on the adoption of this process for the welding of thinner materials. Once under way, this work involved the active cooperation of aircraft and automotive manufacturers in studies concerning the following points:

1. Metal transfer requirements.
2. Wire deposition rates and wire-feed speeds.
3. Constant potential and conventional-type power supplies.
4. Manual and mechanized welding techniques.

Investigation results clearly indicated that the consumable-electrode inert-gas process produces excellent-quality welds in thin-gage materials at high welding speeds. Accordingly, this paper describes the outcome of past investigations in terms of basic problems underlying both manual and mechanized consumable-electrode inert-gas welding with small-diameter wires on thin-gage materials. Discussion also touches on equipment requirements and welding techniques along with some actual applications. The paper is confined to the welding of thin-gage stainless and carbon steels; it omits aluminum since problems associated with the welding of aluminum are distinctly different.

Basic Problems

Type of Metal Transfer

The first point of investigation was the selection of the proper type metal transfer which would permit the consumable-electrode welding of thin materials. It was evident at the beginning of the investigation that two types of metal transfer could be employed. Both are shown in Fig. 1. Referring to the illustration, normal spray-type metal transfer was found most suitable for mechanized downhand welding; and short-arc type metal transfer was found necessary for manual welding, especially in position. The use of this short arc permits the weld puddle to solidify rapidly and stay in the weld joint. The voltage of the spray-type arc generally ranges from 22 to 25 v, compared to a 16 to 21 v range for the short arc. The contact tip-to-work distance, also shown in Fig. 1, represents the electrode extension. The importance of electrode extension is discussed in detail under a separate heading.

Depositing vertical-down fillet weld with consumable-electrode inert-gas process

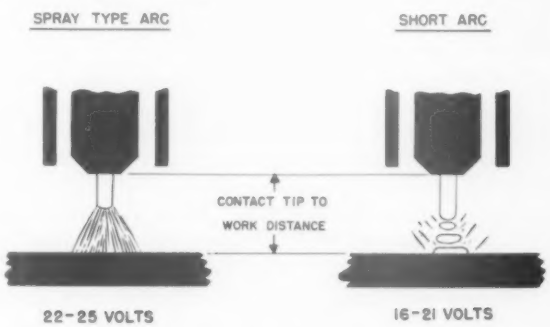


Fig. 1 Comparison of types of metal transfer

K. E. Richter and J. F. M. Essig, (deceased,) Development Engineers, Linde Co., a Division of Union Carbide Corp., New York, N. Y.

Presented at the 1956 AWS National Fall Meeting, Cleveland, Ohio, October 8–12.

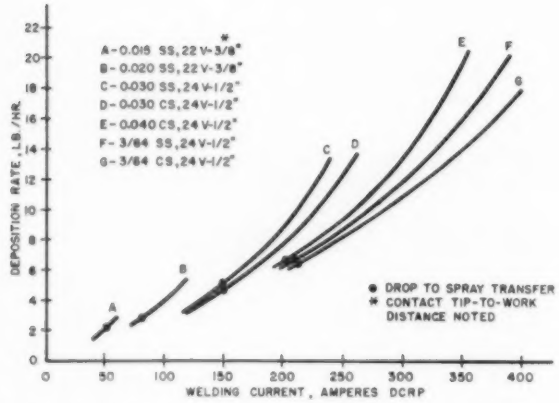

A-0.015 SS, 22 V-3/8*
B-0.020 SS, 22 V-3/8*
C-0.030 SS, 24 V-1/2*
D-0.030 CS, 24 V-1/2*
E-0.040 CS, 24 V-1/2*
F-3/64 SS, 24 V-1/2*
G-3/64 CS, 24 V-1/2*
● DROP TO SPRAY TRANSFER
* CONTACT TIP-TO-WORK DISTANCE NOTED
DEPOSITION RATE, LB./HR.
WELDING CURRENT, AMPERES DCRP

Fig. 2 Metal deposition rates for small-diameter carbon and stainless-steel welding wires

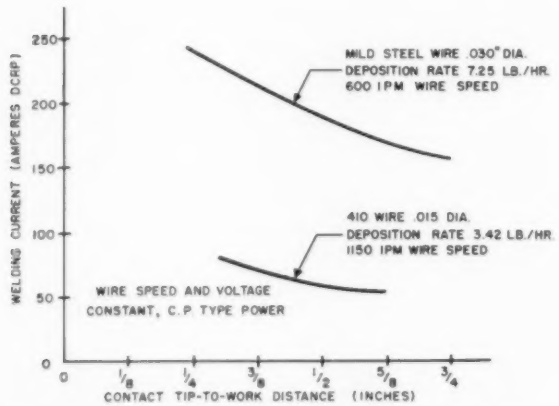

MILD STEEL WIRE .030" DIA.
DEPOSITION RATE 7.25 LB./HR.
600 IPM WIRE SPEED
410 WIRE .015 DIA.
DEPOSITION RATE 3.42 LB./HR.
1150 IPM WIRE SPEED
WIRE SPEED AND VOLTAGE CONSTANT, C.P. TYPE POWER
WELDING CURRENT (AMPERES DCRP)
CONTACT TIP-TO-WORK DISTANCE (INCHES)

Fig. 3 Effect of tip-to-work distance on welding current

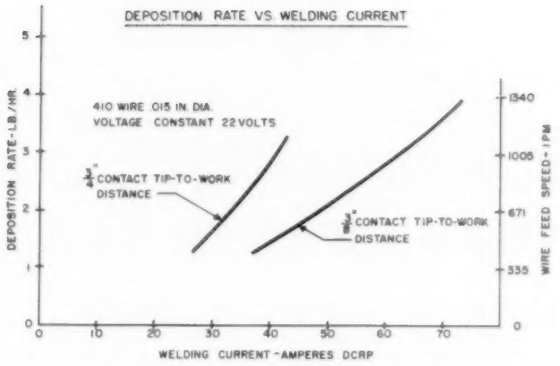


Fig. 4 Effect of tip-to-work distances on deposition

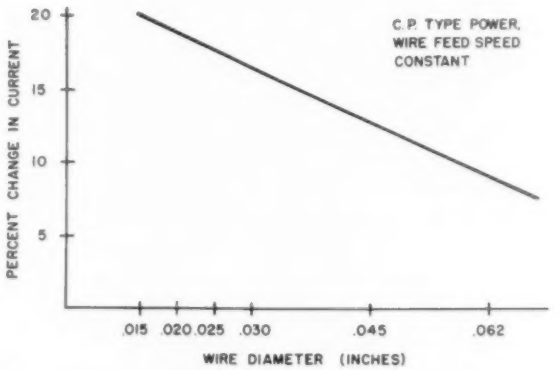


Fig. 5 Effect of a $^1/_8$-in. variance in contact tip-to-work distance

Welding Wire

The success of consumable-electrode inert-gas welding on thin-gage stainless and carbon steel is to a large degree dependent upon the quality of welding wire used. In selecting welding wire, consideration must be given to the following factors: (1) the surface cleanliness of the wire because of its pronounced effect on arc stability; and (2) the type of coiling, and the proper wire stiffness since the wire must feed through close tolerances of the wire-feed system.

The welding of thin-gage stainless and carbon steel requires the use of wires with a diameter of $^3/_{64}$ in. or less. Investigations showed that larger diameter wires such as $^1/_{16}$ in. could not be employed for the welding of thin-gage materials since currents required to obtain the desired metal transfer were excessive. This made it necessary to use smaller diameter wires to obtain satisfactory results. It was, therefore, necessary to determine the wire deposition rates for each of these small-diameter wires within a usable current range and the wire feed speeds at the various welding current levels in order to select the proper wire-drive unit.

Wire deposition rates at different current levels for the various small-diameter stainless and carbon-steel wires used in the investigation are illustrated graphically in Fig. 2. It can be noted that the minimum current required to obtain a spray-type metal transfer decreases from 200 to 50 amp as the wire diameter decreases from $^3/_{64}$ to 0.015 in.

Using currents lower than the transition value at these indicated voltages is not generally recommended due to the type of metal transfer obtained. However, the use of voltages lower than those indicated was found to be practical if the short-arc type metal transfer was desired, provided that a constant-potential type power supply was used. The wire burnoff rate for stainless steel is approximately 10% higher than for carbon steel as illustrated with the 0.030- and $^3/_{64}$-in. wire sizes.

Wire deposition rates increase as the wire diameters decrease for a given current. This is due to the effect of I^2R heating. The wire-feed speed range for $^3/_{64}$-in. diam wire is 150 to 600 ipm, whereas the wire-feed speed range for 0.015-in. diam wire is 300 to 1200 ipm.

Electrode Extension

A factor affecting wire burnoff and thus influencing the type of weld bead obtained is "electrode extension," otherwise described as the distance between the torch contact tip and the workpiece. This distance was found to be more critical when welding with

small-diameter wires than when welding with wires having a diameter of $^1/_{16}$ in. or greater.

Electrode extension affects the amount of I^2R heating, which takes place in the wire. As illustrated by the two curves in Fig. 3, welding current is affected when the contact tip-to-work distance is varied using a constant potential-type power supply and a fixed wire-feed speed. The top curve illustrates the change in current when the contact tip-to-work distance is varied using 0.030-in. diam mild-steel wire at a constant wire-feed speed of 600 ipm. The lower curve illustrates the same condition substituting 0.015-in. diam stainless steel wire at a wire-feed speed of 1150 ipm. In both instances, the contact tip-to-work distance decreases with welding current increases.

The effect of changing the contact tip-to-work distance from $^3/_8$ to $^3/_4$ in. on the welding current and, thus, on weld-metal deposition when using 0.015-in. diam stainless steel wire is shown in Fig. 4. It can be concluded from this graph that it is important to keep the contact tip-to-work distance constant if weld contours are to be duplicated. For example, having a wire deposition rate of 3 lb per hour and a $^3/_4$-in. contact tip-to-work distance, the welding current is 40 amp; whereas, when reducing the contact tip-to-work distance to $^3/_8$ in., the current is 60 amp for the same wire deposition rate of 3 lb per hour. Resulting welds are entirely different in both bead shape and penetration due to this 50% difference in welding current.

Figure 5 illustrates the effect of varying the contact tip-to-work distance by $^1/_8$ in. when using wires ranging in diameter from 0.015 to $^1/_{16}$ in. As the wire diameter decreases, the percentage of welding current change increases for the same $^1/_8$-in. contact tip-to-work distance variation.

As illustrated, all effects caused by varying the contact tip-to-work distance were obtained using a constant potential-type power supply. With a conventional or drooping-characteristic type of power supply, other effects were noted. If, for example, the wire-feed speed is constant, voltage as well as current variations occur. If the wire-feed speed is variable as is the case with voltage control equipment, changes in deposition result. Based on information shown by Figs. 1 through 5, it may be concluded that the skill required for manual welding becomes greater as wire diameters decrease.

Power Supplies

The next point of investigation was to determine the effects of various types of power supplies. When selecting a power supply, the major consideration is the demand placed upon it by the intended application which, in turn, depends on the welding techniques and the wire size selected.

Spray-type metal transfer generally used with consumable-electrode inert-gas welding makes no unusual demands on a power supply. The choice between constant-potential or conventional types of power supplies is largely a matter of personal choice, since both perform satisfactorily with the spray-type metal transfer. When, however, the application requires use of the short-arc technique, additional factors must be considered.

The short arc is actually a series of arc outages. It is thus essential that equilibrium conditions become reestablished in the shortest possible time. Therefore, fast response was found to be a definite requirement of the power supply for short-arc metal transfer. Constant-potential power supplies inherently exhibit a fast response and were found essential for welding with a short arc.

Welding Technique

Manual and mechanized consumable-electrode inert-gas welding of thin-gage stainless and carbon steels results in sound welds and a high operating factor. Fast welding speeds at low welding currents minimize distortion. This is important when welding thin-gage material. The shielding gas, which protects the weld puddle from the atmosphere, is usually argon which contains 5% oxygen for improved arc stability. Joint design, preparation and alignment should be carefully controlled for both manual and mechanized welding. Mechanical wire brushing or degreasing improves the quality of the welds in many instances. The use of metal weld backing such as copper or stainless steel or a gas backing such as argon, helium or nitrogen will depend upon the material, type joint and desired weld quality.

Adequate jigging is one of the keys to successful welding. Insufficient hold-down pressure allows the thin-gage sheets to "crawl." This results in varying joint-gap spacing between the start and finish of the weld. Penetration and weld bead contour are affected by any changes in joint opening. Hold-down pressures in the order of 400 to 600 lb per linear inch are required

Fig. 6 Downhand fillet weld on 16-gage stainless steel

Fig. 7 Cross section of manual downhand fillet weld in 16-gage stainless steel

Fig. 8 Cross section of manual vertical-down fillet weld in 16-gage stainless steel

Fig. 9 Cross section of manual overhead fillet weld in 16-gage carbon steel

to prevent movement of the thin sheets during welding.

Manual welding in position or downhand using a small-diameter wire such as 0.030 in. to weld 16-gage

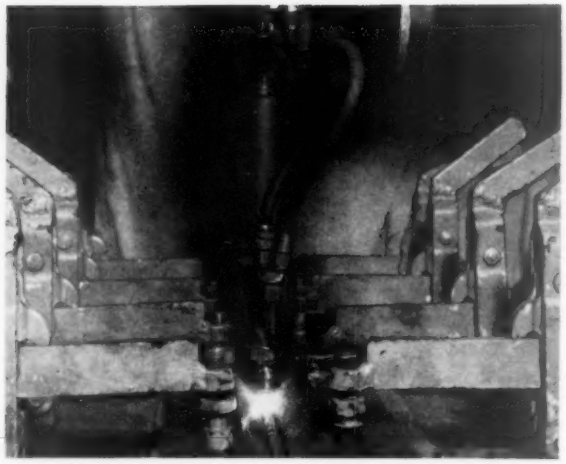


Fig. 10 Mechanized butt weld on 20-gage stainless steel

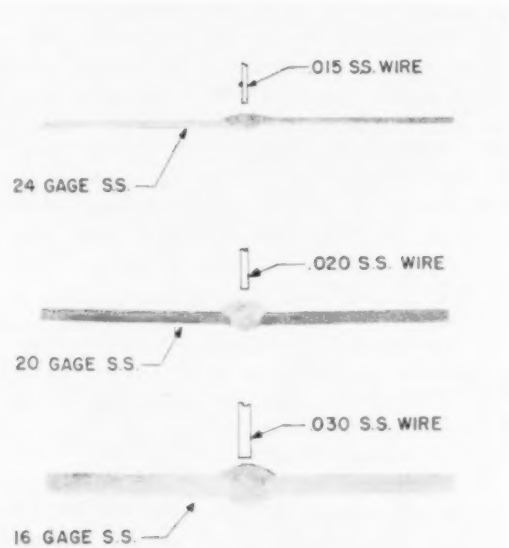


Fig. 11 Cross sections of mechanized butt welds in three different thicknesses of stainless steel

material requires a greater amount of skill on the part of the operator than is required to weld 11- or 12-gage material with $^{3}/_{64}$ or $^{1}/_{16}$-in. diam wire. It is necessary for the operator to control the contact tip-to-work distance closely when using smaller-diameter wires as previously mentioned. With a little practice, however, most operators, who have had experience with manual consumable-electrode inert-gas welding equipment, can master the techniques and weld in all positions. As an example, Fig. 6 shows a downhand fillet weld being made on 16-gage stainless steel at a speed of 22 ipm. The operator is using a short arc, 0.030-in. stainless steel wire, 120-amp direct current-reverse polarity (DCRP), and 35 cfh of M-5 argon. A cross section of this weld is shown in Fig. 7. A vertical-down fillet weld made on the same material using the same welding conditions is shown by Fig. 8 in cross-section

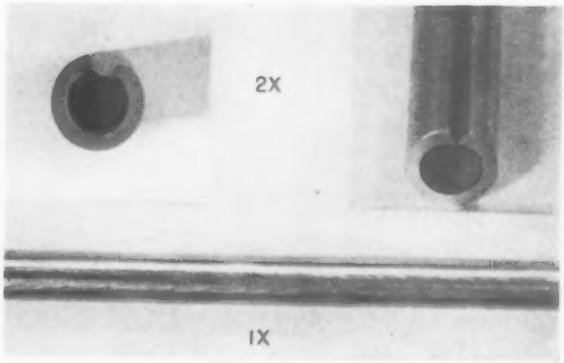


Fig. 12 Magnified longitudinal weld in $^{17}/_{32}$-in. OD stainless-steel tubing (cross section and joint preparation included). (Reduced by 50% upon reproduction)

Fig. 13 Welded gear assembly for automotive transmissions (hub, flange and gear)

Fig. 14 Welded assembly for automotive transmissions (shell and skirt)

form. Similarly, Fig. 9 shows the cross section of an overhead fillet weld, which was made on 16-gage carbon steel at a speed of 22 ipm using a short 20 v arc and 0.030-in. diam wire.

For manual welding, a high degree of operator skill is required. For mechanized operations, however, a lesser degree of operator skill is required and mechanization is conducive to more reliable results. Accordingly, mechanized consumable-electrode inert-gas welding has proved practical on thin-gage material in automotive and aircraft industries. The use of mechanized consumable-electrode welding with small-diameter wire has resulted in increased production, lower welding costs and a more uniform weld quality.

As an example of mechanical welding with the consumable-electrode process, Fig. 10 shows a butt weld being made on 20-gage stainless steel using a 22-v arc and 0.020-in. diam stainless-steel wire. The contact tip extends below the shielding gas nozzle since a $^{3}/_{8}$-in. contact tip-to-work distance is being used.

In Fig. 11, the cross sections of three butt welds are shown as made without the use of a backing; penetration that can be obtained is also illustrated. The top view in Fig. 11 represents a butt weld on 24-gage stainless steel made using 0.015-in. diam wire, 75-amp DCRP and a $^{3}/_{8}$-in. contact tip-to-work distance. The middle cross section depicts a butt joint on 20-gage stainless steel made using 0.020-in. diam wire, 120 amp and a $^{3}/_{8}$-in. contact tip-to-work distance. The lower cross section represents a butt weld on 16-gage stainless steel made using 0.030-in. diam wire, 145 amp and a $^{1}/_{2}$-in. contact tip-to-work distance. All three butt welds were made mechanically using 35 cfh M-5 argon at a welding speed of 50 to 60 ipm with the spray-type of metal transfer.

Typical Applications

Four uses of consumable-electrode inert-gas welding with small-diameter wire are described below: the welding of thin-gage, small-diameter stainless-steel tubing—application of the process to assemblies used in automotive transmissions—use of the process for welding jet-engine components and for assembling a jet-fuel-tank storage and shipping container.

Figure 12 illustrates results obtained when welding stainless-steel tubing. In this application, longitudinal butt welds were made in $^{17}/_{32}$-in. OD tubing with a 0.090-in. thick wall. Welding was carried out on a joint beveled to 60 deg at 33 ipm using 0.030-in. diam stainless-steel wire.

Different aspects to the welding of carbon-steel assemblies for automotive transmissions are shown in Figs. 13, 14 and 15. Figure 13 illustrates the internal gear assembly after the hub was welded to the flange at 85 ipm and after the flange was secured to the gear by means of six tack welds. Figure 14 illustrates the

Fig. 15 Cross section of circumferential lap fillet weld

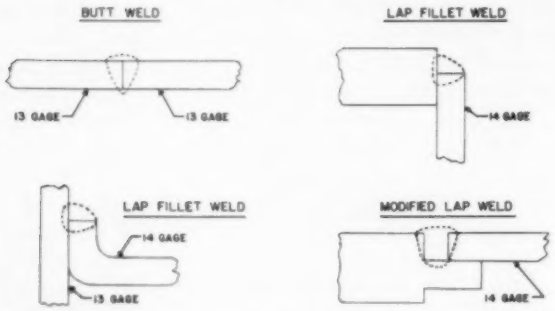


Fig. 16 Four typical circumferential welds for jet-engine components made with $^{3}/_{64}$-in. diam wire

Fig. 18 Circumferential butt weld for storage and shipping container

results of a subsequent operation where a 16-gage carbon steel shell was joined to an 11-gage carbon steel skirt by means of circumferential lap fillet welding at 90 ipm; a cross section of the joint is shown in Fig. 15. All welds were made with 0.040-in. diam carbon steel wire.

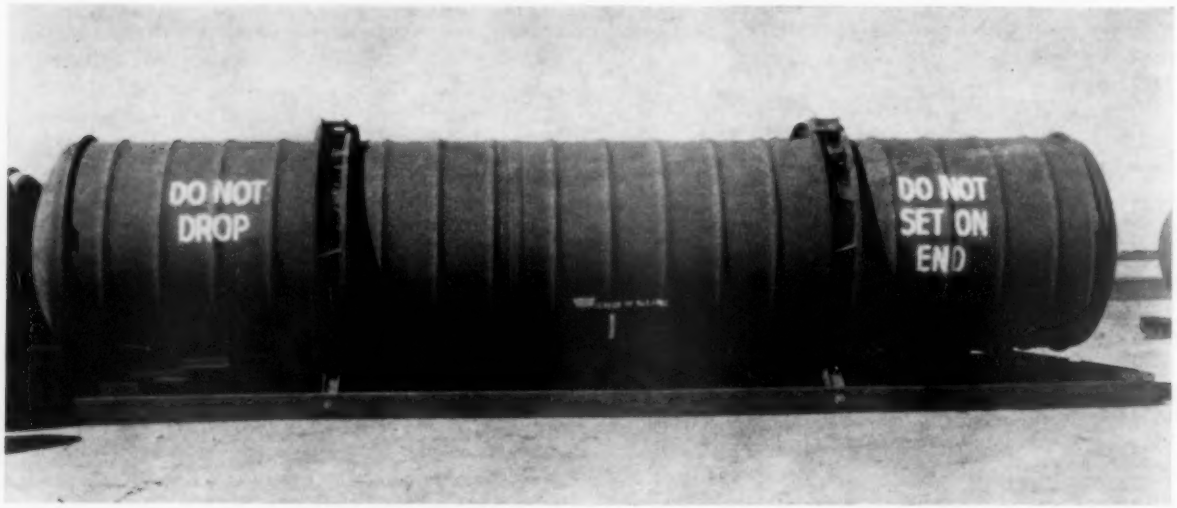


Fig. 17 Welded jet-fuel storage tank and shipping container

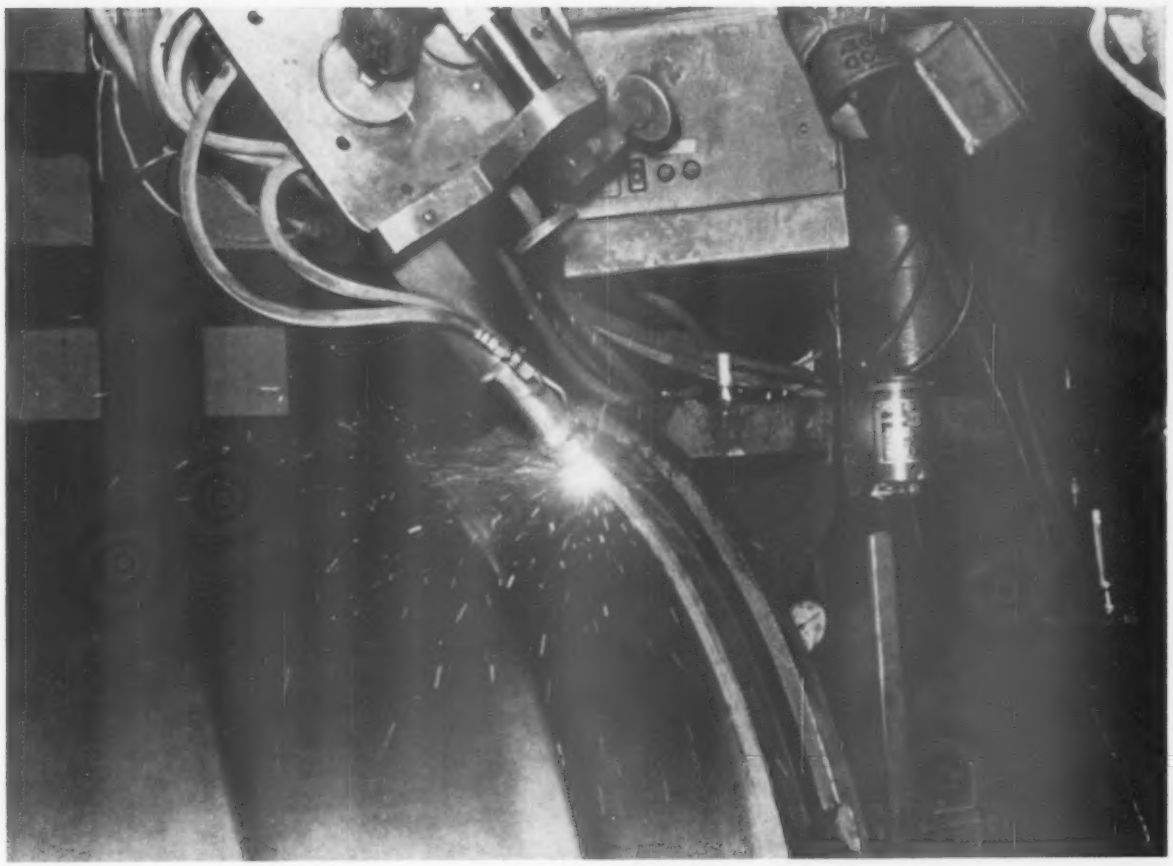


Fig. 19 Circumferential lap weld for storage and shipping container

Four different but typical circumferential welds as are now being made in jet-engine components with $^{3}/_{64}$-in. diam stainless-steel wire are shown schematically in Fig. 16. Similarly, four different circumferential welds were made during the fabrication of the large carbon-steel container for shipping and storing jet fuel tanks shown in Fig. 17. One of the four welds was a butt weld in 20-gage carbon steel. In the butt-welding operation illustrated by Fig. 18, a solid backing was used during actual welding; and the weld was made at 42 ipm with 0.030-in. diam wire and a short arc. The second circumferential weld was a lap weld, and the third was a fillet weld. Figure 19 illustrates the lap weld as it was made with 0.030-in. diam wire at 90 ipm, and Fig. 20 shows the fillet weld being made at 94 ipm with 0.030-in. diam wire and a spray-type arc. The fourth and final weld was a butt weld joining two $^{1}/_{8}$-in. thick angle sections at 36 ipm with $^{3}/_{64}$-in. diam wire.

Conclusion

Based on work to date, inert-gas consumable-electrode welding with small-diameter wires is a major advance in the art. Its higher speeds, lower cost and resulting excellent-quality welds are sufficient incentives to warrant serious consideration of the process for many applications in light-gage materials.

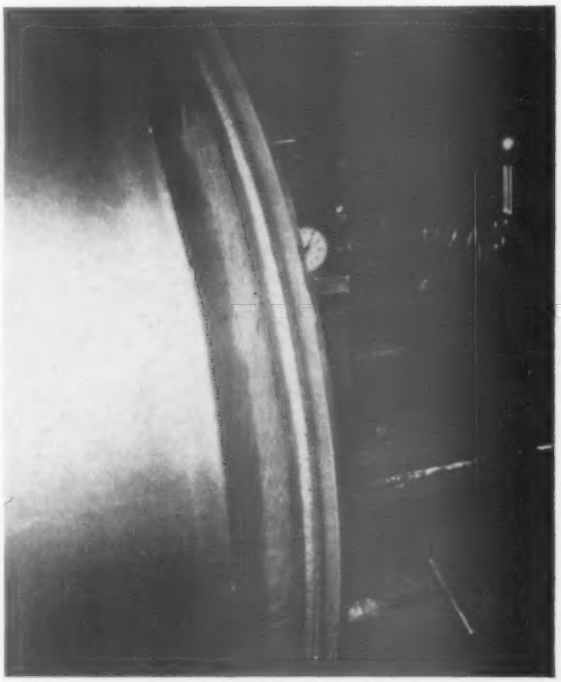


Fig. 20 Circumferential fillet weld for storage and shipping container

HOW TO SLICE THICK STEEL WITH OXYGEN CUTTING

Oxygen cutting is the fastest and most economical method of severing iron and steel. It utilizes the rapid chemical reaction between heated iron and oxygen: when iron is heated red hot and exposed to high-purity oxygen, an intense reaction takes place; enough heat is liberated to melt the iron oxide that is formed and also heat some of the unoxidized iron or steel to a point where it too becomes liquid.

Under the influence of this heat, the oxide formed is molten and flows or is blown away, exposing more metal to the action of the oxygen.

However, due to the chilling effect of the surrounding metal and the cutting-oxygen stream, the heat resulting from the reaction is not enough to keep the reaction going. For this reason, oxyacetylene cutting torches provide one or more small oxyacetylene flames for preheating (see Fig. 1). During the operation, these flames supply heat to the point of cutting—keeping the metal at a red-hot temperature where it will react with the cutting-oxygen stream.

With a cutting attachment on your oxyacetylene welding torch, you can cut through steel up to 8-in. thick. But with a heavy-duty cutting torch, you can make smooth, high-quality cuts in heavy steel sections up to 12-in. thick—and in a matter of minutes too.

To cut such thick steel, first point your torch slightly away from the work and use the preheat flames to heat a small area at the start of the line of cut (see Fig. 2). When the spot on the top surface turns bright red and begins to melt, press down the oxygen lever.

The oxygen quickly slices a narrow slit or kerf through the steel. When you cut 12-in. thick steel, your oxygen pressure must be between 80 and 90 lb per sq in. to provide enough force to blow the liquid iron oxide out of the cut.

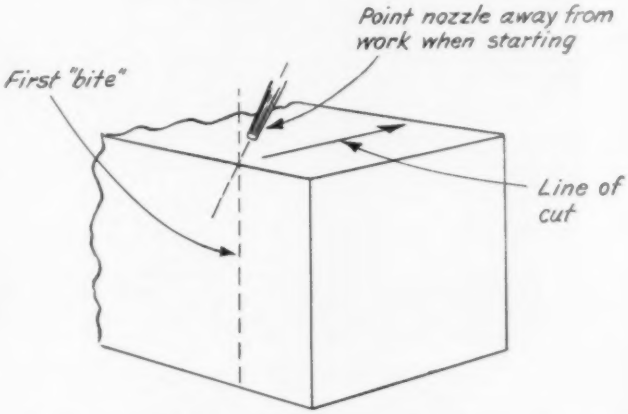
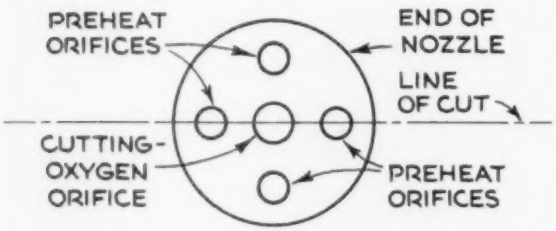


Fig. 2 Heat a bright red spot at the start of the line of cut. When the spot begins to melt, turn on the cutting oxygen. This cut is being made in a steel slab 12-in. thick

Fig. 3 Straighten the torch so that the nozzle is straight up and down. Begin moving the blowpipe as soon as the cut is all the way through the 12-in. thick steel

Based on a story by the Linde Co., New York, N. Y.



NOZZLE SETTING FOR SQUARE CUT

Fig. 1 Be sure to use the correct nozzle for the job. Place the nozzle in the torch so that the preheating flames heat the steel ahead of the cutting-oxygen stream

Once the cut is started, turn the torch into the work so that the nozzle is straight up and down (see Fig. 3). When the cut goes all the way through the steel, move the torch steadily along the line of cut. And don't move too fast—this is thick steel (see Figs. 4 to 7).

Fig. 4 Steadily follow the line; the cut should be going straight through the work. And remember: this is thick steel—don't move too fast or you'll lose the cut

Fig. 6 The cut should come through the side of the work from the bottom to the top. Continue moving steadily until you've finished the job

Fig. 5 Using the angle iron as a pivot, swing the blowpipe slightly forward as you move along. Maintain the pivoting action by rolling your hand supporting the blowpipe

Fig. 7 By moving the blowpipe at a steady rate, you can make a smooth, high-quality cut like this one. This 120-sq in. section was sliced cleanly in 120 seconds

CARRYING COAL TO NEWCASTLE WAS NEVER LIKE THIS

Before long, coal should be flowing over the hills of Ohio through this 10-in. pipe line, running 108 miles from the Hanna Coal Co. strip mines, south of Cadiz, Ohio, to the Cleveland Electric Illuminating Co.'s Eastlake Generating Plant, just east of Cleveland. The coal, pulverized and suspended in water, will be pumped through the line at a rate approximating $3^1/_2$ mph, then dried and fed into the station steam generating boilers. It is anticipated that the line will be capable of delivering 1,300,000 tons of coal each year.

Based on a story by the Lincoln Electric Co., Cleveland, Ohio.

The Pittsburgh Consolidation Coal Co., after 5 years of research, decided that this was a feasible way to transport coal and is now in the process of making this idea a reality.

The line, the first of its kind in the United States, involved some interesting welding, since, because of the erosive-corrosive nature of the material being transported through the pipe, it was necessary to use heavy wall sections and high-tensile steel (see Figs. 1–4). Five different pipe wall thicknesses were used. Sixteen

Fig. 1 The line-up gang, stringer pass and hot pass welders approach Lake Erie and work under the high voltage transmission lines coming from the power-generating plant to which this pipe line will carry coal

The crews averaged better than $2^1/_2$ miles a day, in spite of unusually wet weather.

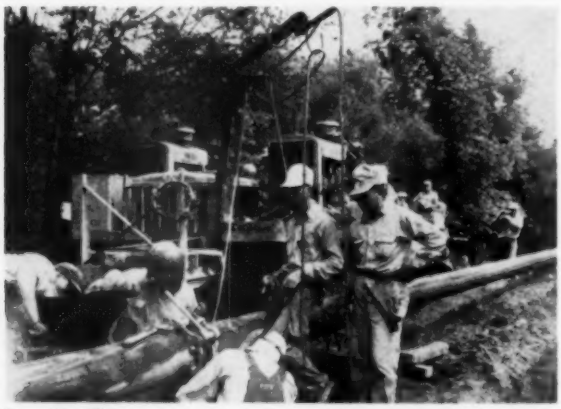


Fig. 2 These stringer pass welders are using $^5/_{32}$-in., E6010 electrodes and two 300-amp diesel-driven welders mounted on the rig in the background

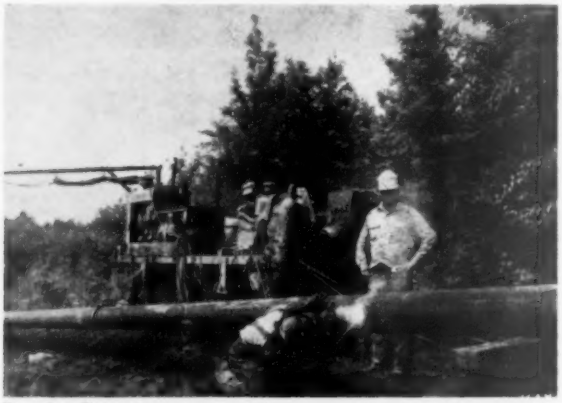
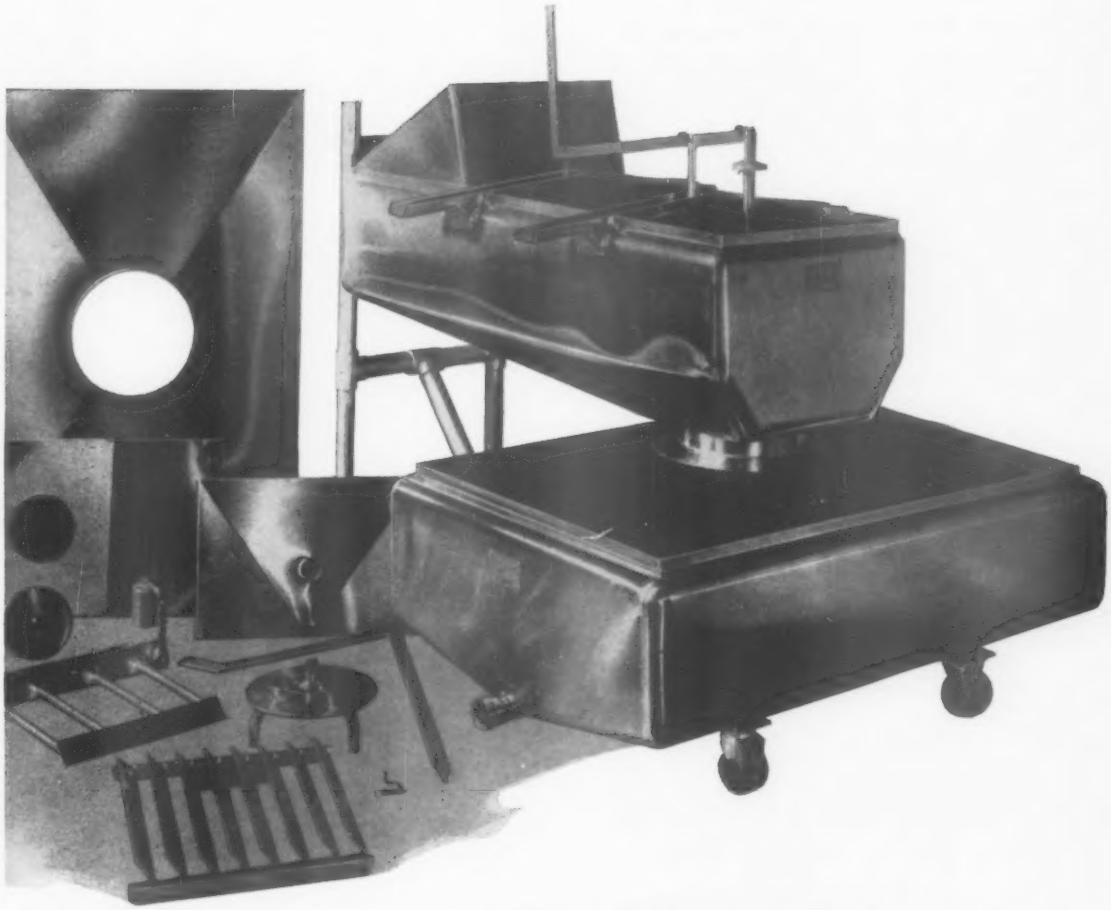


Fig. 3 Three hot pass welders are using the rig, mounting two diesel-driven welders and one gasoline engine-driven welder

Two hot passes were made, using $^5/_{32}$-in., E7010 electrodes.

Fig. 4 Part of the filler pass gang of 12 welders are shown here

The $^7/_8$-in. wall pipe was welded with 16 passes; $^1/_2$-in. wall, with 11 passes. Approximately 150 welders were tested to qualify the 22 used on the line. E7010 electrodes of $^3/_{16}$-in. size were used for filler passes.



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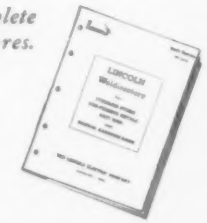
For quality and speed on stainless steel, there's no equal to Lincoln Stainweld electrodes.

Their easy operating characteristics make Stainweld well-suited for both flat and out-of-position work—overhead, vertical up or vertical down.

Special types available for 18-8, 18-12, 25-12, and 25-20 stainless steels.

Bulletin SB-1352 has complete specifications and procedures. Write for it.



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When Stainweld electrodes **Have** peak dependability **Yet** save you money

WHY USE ANYTHING BUT STAINWELD FOR STAINLESS?

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passes were used on the heavy-wall pipe. All pipe used was 5LX-42 specification. The bulk of the pipe was furnished with a 30-deg bevel for welding on the end. A relatively small amount of pipe was furnished with $37^1/_2$-deg bevels. Stringer beads were used for all passes, except the cap pass which was a wide weave. In cold weather, pipe was welded without preheating by not allowing the pipe to cool between passes. Filler pass welders moved in quickly behind stringer and hot pass welders. Filler pass welders would keep two joints hot at the same time by alternating their welding back and forth between the two joints. In order to prevent underbead cracking, it was necessary to have stringer bead welders strip 3 in., top and bottom, before moving pipe to make the next line-up. E6010 $^5/_{32}$-in. diam electrodes were used for stringer passes; E7010 electrodes were employed for two hot passes; and $^3/_{16}$-in. E7010, for filler passes. E6010 electrode was used for the cap pass. The line used two men welding stringers, 3 on hot passes and 12 on filler passes. Three diesel engine-driven welders and 19 gasoline engine-driven welders supplied the welding crews.

ALUMINUM-BRONZE FABRICATED HAWSE PIPES FOR LONGER SERVICE LIFE

BY WILLIAM F. HOFFMANN

Hawse pipes similar to the one shown in the accompanying Fig. 1 are fabricated in the shops of Peterson Builders, Inc., at Sturgeon Bay, Wis., in construction work relative to the Navy minesweeper program. This company also produces a wide selection of quality barges, pleasure boats and sail boats by modern manufacturing methods for use in inland and coastal waters.

The hawse pipes are fabricated from manganese-bronze cast sections welded together with ECuAl-A2 spooled wire and the inert-gas metal-arc process to secure the highest quality joints possible at the lowest cost.

The edges of the cast sections are prepared to provide a single U-groove 2-in. deep and $1^1/_2$-in. wide at the top upon assembly. The joints require ten layers of weld metal depositing $^1/_{16}$-in. ECuAl-A2 wire with reverse polarity, direct current at 350 amp and 29 volts. Argon gas was used with a wire feed of 300 ipm. No preheat or postheat treatment was required.

To resist wear and assure a long life, the area of the hawse pipe coming into contact with the Hadfield steel chain is subsequently overlaid with one layer of ECuAl-A2 and the inert-gas metal-arc process to provide a good bond with the manganese bronze. Then the ECuAl-A2 deposit is overlaid with RCuAl-D 36-in. filler rods and the inert-gas tungsten-arc process to provide a hard wear-resisting deposit (310-340 Brinell).

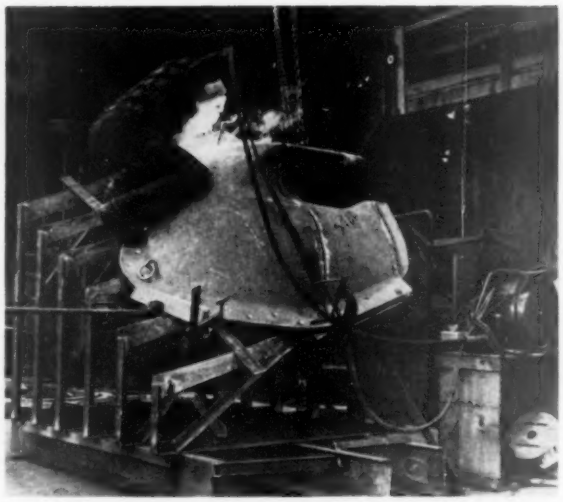
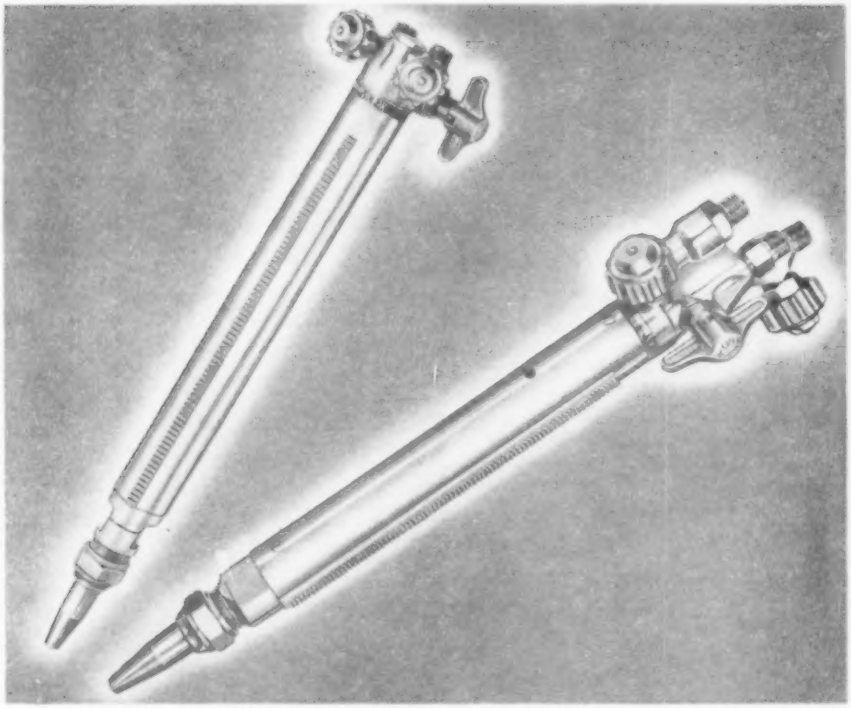


Fig. 1 Hawse pipes being fabricated from manganese-bronze cast sections welded together with ECuAl-A2 spooled wire and inert-gas metal-arc process

William F. Hoffmann is associated with Machinery & Welder Corp.
All photos court esy of Ampco Metal, Inc., Milwaukee, Wisc.



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MT-200 LPCG SERIES for low or medium pressure fuel gases such as city, natural or petroleum gases.

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Designed for general purpose machine cutting. All commercial fuel gases commonly used for machine cutting can be utilized by selection of the proper size and type of Victor cutting tips and torch model.

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For more details, circle No. 9 on Reader Information Card

Society News

Irving Joins Welding Journal Staff

On May 1, 1957, Robert R. Irving joined the staff of THE WELDING JOURNAL in the capacity of assistant editor. In his new position Mr. Irving will participate in the over-all editorial responsibilities as well as in the promotion of advertising. A native of Philadelphia, he is 30 years of age.

Mr. Irving graduated from the University of Pennsylvania in 1951 with

Robert R. Irving

a Bachelor of Arts degree. While at Penn, he was a member of Delta Tau Delta Fraternity.

Prior to coming to the AWS, Mr. Irving was employed in the welding division of Morris, Wheeler & Co., Inc., in Philadelphia in purchasing and sales capacities. Active in the Philadelphia Section of the American Welding Society, he served three years in the appointed post of assistant secretary and also edited the Section's meeting notice bulletin. Mr. Irving was the secretary of the Philadelphia arrangements committee during the recent AWS Annual Show and Adams National Meeting in April.

Schultz Named Director of District 5

On May 31, 1957, District 5 of the AMERICAN WELDING SOCIETY elected Harold E. Schultz as District Director to fill the vacancy created by the death of Lew Gilbert.

Harold E. Schultz, Manager of Applications and Processes Engineering at General Electric, Evendale, Ohio, is a graduate of Oklahoma A. & M., joined

Harold E. Schultz

General Electric in 1942, serving first in the Engineering Test Program. From 1943 to 1951 he was a Welding Engineer at the Thompson Laboratory, General Electric River Works, Lynn, Mass., and in the spring of 1951 received the assignment of organizing and heading up the Welding Unit of the Aircraft Gas Turbine Plant Laboratory in Evendale, Ohio. This led, in 1953, to the position of Manager of Welding and Heat Treatment in the Materials Laboratory of the AGT Development Department. His present duties include the application of new developments in the field of processes, materials, etc. to advanced jet engine design and manufacture.

He is a member of the AMERICAN WELDING SOCIETY, a former member of the Executive Committee, Cincinnati Section, and a past Chairman of the Section. He also maintains active membership in the Aircraft Advisory Committee of the Welding Research Council, and the Resistance Welding Committee. He also served as the General Chairman of the Central States Welding Conference held in Cincinnati during the spring of 1957.

AWS DIRECTORS-AT-LARGE

Term Expires	1958	1959	1960
	F. H. Dill	J. H. Blankenbuehler	J. F. Deffenbaugh
	E. D. Peters	G. E. Linnert	A. E. Pearson
	J. L. Wilson	P. G. Parks	C. M. Styer
	R. J. Yarrow	F. H. Stevenson	R. M. Wilson, Jr.

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Junior Past-President	F. L. Plummer	*Junior Past-President*	J. J. Chyle

For more details, circle No. 10 on Reader Information Card→

USS TECHNICAL WELDING DATA

3

Effect of Welding on Notch Toughness of USS "T-1" Steel

THE EFFECT OF WELDING on the notch toughness of steel is normally determined by Kinzel-type notch-bend tests on welded and unwelded plate in the quenched and tempered condition. Details of the welded plate specimen are shown in Figure 1. The unwelded specimens are identical to the welded, except for the omission of the weld. The plate temperature prior to welding is 70° F., and after welding, the specimens are aged at 50-80° F. for a minimum of three weeks. The specimens in sets of about 25 are then bent at various temperatures with the weld bead in tension as shown in Figure 1. In general, three specimens are tested at each temperature.

INFORMATION DETERMINED FOR EACH SPECIMEN TESTED

1. Total (maximum) angle of bend and angle of bend at maximum load. Obtained from deflection-angle curve.
2. Fracture mode expressed as per cent shear. Obtained by observation of fracture.

The data obtained are plotted on the basis of testing temperature, and envelopes are drawn around the plotted points to indicate the amount of scatter. The curves for ½"-thick USS "T-1" Steel plate welded with E-12015 electrodes are shown in Figure 2. The data are for specimens taken longitudinal to the final rolling direction of the plate.

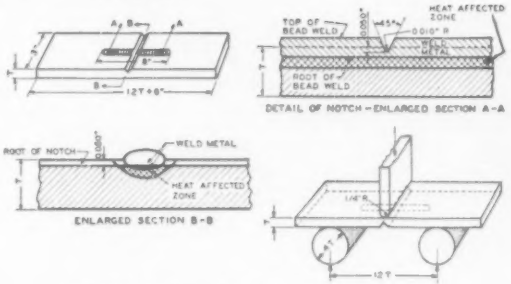
TO DETERMINE DUCTILITY-TRANSITION TEMPERATURES, the middle of the temperature range in which the total angle of bend drops rapidly to a low value is chosen. This is the temperature at the middle of the "scatter band" in the angle of bend curve in Figure 2.

THE FRACTURE-APPEARANCE-TRANSITION TEMPERATURE is also determined. As used here it is the temperature at which 50% of the fracture occurs in the shear mode, i.e., 50% of the fracture is fibrous. Typical curves are shown in Figure 2.

The results of notch-toughness studies on ½"-thick plate are given in the Summary, below. The Summary includes data for Regular Quality plate as well as data for Firebox Quality plate.

It should always be borne in mind that at the present time there is no absolute correlation between transition temperature as obtained experimentally with the various types of specimen and service performances. *Results obtained from the same types of tests on different steels should be very useful in establishing the relative merit of the steels.*

REMEMBER THIS: No other alloy steel offers the combination of properties that "T-1" Steel possesses. Here, in just one steel, you get very high yield strength (90,000 psi minimum), extraordinary toughness, great resistance to impact abrasion, and good high temperature strength. These let you reduce the size of highly stressed parts . . . save weight, reduce the amount of welding required and cut your costs. USS "T-1" Steel is being used in bridges, excavating equipment, pressure vessels, towers . . . in equipment that must take heavy abuse in sub-freezing temperatures . . . in equipment that must withstand heavy stresses and impact abrasion at temperatures as high as 900° F.



WELDING CONDITIONS: electrode diameter 3/16"; current (amps) 180; voltage 27; speed of travel (in./min.) 6.0; heat input (watt sec./in.) 48,000.

Fig. 1. Details of Kinzel-type notch-bend specimen and of testing jig.

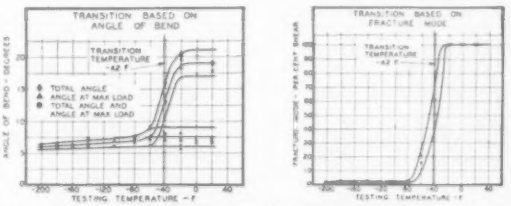

TRANSITION BASED ON ANGLE OF BEND
TRANSITION TEMPERATURE -42 F
TOTAL ANGLE
ANGLE AT MAX LOAD
TOTAL ANGLE AND ANGLE AT MAX LOAD
ANGLE OF BEND - DEGREES
TESTING TEMPERATURE - F
TRANSITION BASED ON FRACTURE MODE
TRANSITION TEMPERATURE -42 F
FRACTURE MODE - PER CENT SHEAR
TESTING TEMPERATURE - F

Fig. 2. Measurements and transition-temperature selection criteria in Kinzel-type notch-bend test.

Summary of notch-toughness test data on ½" USS "T-1" Steel plate (heat No. 74L236)

Test	Type of Plate	Specimen Orientation	Specimen Condition	Ductility-Transition temp., F.*	Fracture-Appearance-Transition temp., F.**
Kinzel notch-bend	Firebox Quality	Long.	Unwelded	minus 68	minus 67
Kinzel notch-bend	Firebox Quality	Trans.	Unwelded	minus 62	minus 59
Kinzel notch-bend	Regular Quality	Long.	Unwelded	minus 130	minus 128
Kinzel notch-bend	Regular Quality	Trans.	Unwelded	minus 91	minus 91
Kinzel notch-bend	Firebox Quality	Long.	Welded†	minus 42	minus 42
Kinzel notch-bend	Firebox Quality	Trans.	Welded†	minus 50	minus 47
Kinzel notch-bend	Regular Quality	Long.	Welded†	minus 92	minus 89
Kinzel notch-bend	Regular Quality	Trans.	Welded†	minus 112	minus 112
Kinzel notch-bend	Firebox Quality	Long.	Welded and stress-relieved‡	minus 30	minus 27

* *Taken at middle of bend*
** *Selected at 50% shear*
† *E12015 electrodes*
‡ *E9015 electrodes; Stress-relieved at 1100°F. for 1 hr.*

FOR COMPLETE INFORMATION about the application and fabrication of USS "T-1" Steel, write for our new comprehensive booklet to United States Steel, Room 2801, 525 William Penn Place, Pittsburgh 30, Pa.

USS "T-1" CONSTRUCTIONAL ALLOY STEEL

"USS" and "T-1" are registered trademarks

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Phillips Appointed Secretary to EAC

Arthur L. Phillips, editor of the WELDING HANDBOOK, has been appointed Secretary to the Educational Activities Committee for the current year. He will continue his editorial duties and devote his time to both activities.

Educated in England, Mr. Phillips has American, Canadian and British industrial and editorial experience. In the editorial field he has done feature writing and technical magazine editing.

He has written and directed motion pictures on welding and prepared the script for film strips and the slides for educational lectures. He has written lectures on specific aspects of welding and prepared a correspondence course on practical welding. Under his supervision a week's training course was prepared and recorded and an explanatory, fully illustrated booklet designed which the student studied while the records were played.

Mr. Phillips joined the staff of the AMERICAN WELDING SOCIETY in 1955.

Welding Courses at Drexel

The Philadelphia Section of the AMERICAN WELDING SOCIETY will sponsor two welding courses this coming year at the Evening College of Drexel Institute of Technology. Each of the two courses will be offered in three parts of twelve weeks each on Tuesday evenings from 7 to 9:40 P.M.

The basic course, "Principles of Welding Engineering," will deal with welding processes, welding design, codes and specifications and inspection. The advanced course, "Elements of Welding Metallurgy," cannot be taken without the successful completion of the basic course. Among the topics to be studied are the effects of heat on ferrous and nonferrous metals and the uses of rod coatings and flux.

More particulars on the program will be presented at the Philadelphia Section's monthly meeting on September 16th at Drexel Institute.

This educational program was inaugurated in 1952.

WELDERS ENCOURAGED

Richard C. Wiley of California Polytechnic Institute, chief judge for the California "Future Farmers of America" statewide welding competition, is seen here accepting the trophy from W. W. Walker, AWS Student Chapter chairman. By means of this contest Cal Poly's Chapter will endeavor to promote an interest in the welding field throughout the high schools of California.

Cal Poly Student Chapter Active

During the past summer the AWS student chapter at California State Polytechnic College initiated a summer employment program in conjunction with the San Jose Section. Questionnaires were mailed to various employers who were active in AMERICAN WELDING SOCIETY functions to determine each firm's interest in such a program. Then each student was evaluated for his ability toward various occupations and a list of applicants was submitted to each prospective employer. This was an interesting attempt to qualify students for the right job.

New AWS Supporting Company Members

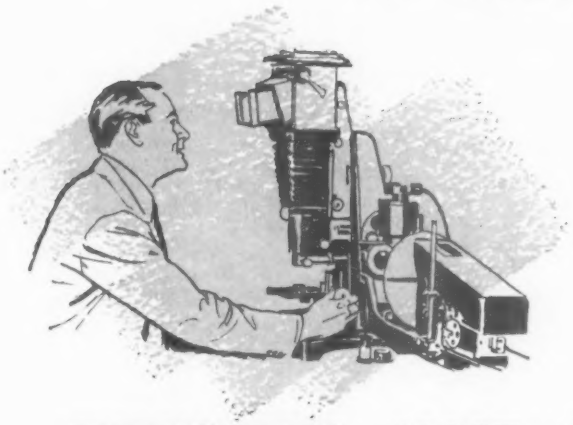
Four new Supporting Company Member enrollment applications have been received from the following organizations:

All Metal Mfg. Co., 2740 W. 50th St., Chicago, Ill.

By-Law Amendments Approved

Temporary By-laws, voted by AWS Board of Directors at their meeting on April 11, 1957, have now been approved by members of the Society. Balloting closed on Aug. 15, 1957. Report of the Tellers Committee discloses that the number of negative votes was far below the number required for rejection of any amendment and that most amendments were approved almost unanimously.

Now available to help you...



INDUSTRY'S MOST COMPLETE RESISTANCE WELDING APPLICATION RESEARCH FACILITIES

In response to industry's rapidly growing interest in resistance welding, the facilities of the Sciaky Research Division have been made available for contract research in the application of resistance welding.

These facilities include an experienced engineering staff, a complete range of the most advanced resistance welding machines including the largest spot welder in the world and a laboratory equipped for metallography, chemistry, electronics, photography and testing as applied to resistance welding.

Typical projects include: Coordination of design and production for resistance welding; research on the weldability of new metals; investigation of weldability and pilot run of new product; research to develop data for roll spot welding heavy gauges of aluminum.

If you have a fastening requirement, here is the place to determine objectively the feasibility of resistance welding. Send an outline of your problems and ask for the 20-page Research Division brochure. Sciaky Bros., Inc., 4919 W. 67th St., Chicago 38, Ill., POrtsmouth 7-5600.

The Sciaky Research Division is housed in this modern 15,000 sq. ft. building devoted exclusively to research in the application of resistance welding.

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Chain Belt Co., 4701 W. Greenfield Ave., Milwaukee, Wis.

Gorham Mfg. Co., 333 Adelaide Ave., Providence 7, R. I.

Service Mfg. & Supply Co., 315 E. State Fair, Detroit 3, Mich.

All these enrollments became effective on Aug. 1, 1957.

Miller Electric Adds to Sustaining Membership

An additional Sustaining Membership in the AMERICAN WELDING SOCIETY has been obtained by Miller Electric Mfg. Co., Inc. of Appleton, Wis.

Miller Electric was incorporated in 1929 as manufacturers of a-c arc welders. They now manufacture a-c and d-c welders, a-c/d-c combination welders, gasoline-driven arc welders and spot welders in various sizes. In a-c welders, Miller builds models ranging from 100 to 1500-amp output. Selenium rectifier type d-c arc welders are manufactured in sizes ranging from 200 to 600 amp. Duplex models are made in three sizes from 600 to 1200 amp. A-c high-frequency inert-gas welders are also available in three sizes. Constant voltage type d-c welders are made in 300, 500, and 1000 amp. Miller also manufactures a-c and d-c gasoline engine driven welders, combination power plants and spot welders, both portable and stationary.

The new Sustaining Member representative is C. B. Abel.

Insley Manufacturing Now A Sustaining Member

Insley Manufacturing Corporation became a sustaining member of the AMERICAN WELDING SOCIETY. The organization maintains general offices and factory in Indianapolis, Ind. West Coast division offices and factory are maintained in LaPuente, Calif., while a wholly owned subsidiary, The Maxi Corp. operates in Los Angeles, Calif.

Product line includes: crawler or rubber mounted shovels, backhoes, cranes, clamshells, draglines, magnet cranes and log loaders. Additional products include self-propelled carriers for cranes and concrete handling equipment consisting of buckets, carts and hoppers.

The Sustaining Member representative is H. T. White.

For more details, circle No. 13 on Reader Information Card

Socony Mobil Becomes AWS Sustaining Member

Socony Mobil Oil Co. is one of the latest organizations to become a sustaining member of the AMERICAN WELDING SOCIETY.

Socony Mobil is a major supplier of high quality petroleum products used in the automotive, marine, industrial, aviation, railroad and agricultural fields and in the home. Among petroleum products marketed by the company, nearly all under the Mobil brand, are gasoline, motor oils and greases, industrial waxes, liquefied petroleum gas, certain petrochemicals and industrial paints.

Socony Mobil owns and operates 18 refineries and 3 paint plants. Its 12 refineries in the U. S., listed in order of crude-oil capacity, are situated at Beaumont, Tex.; Torrance, Calif.; Paulsboro, N. J.; East St. Louis, Ill.; East Chicago, Ill.; Ferndale, Wash.; Augusta, Kans.; Trenton, Mich.; Buffalo, N. Y.; Brooklyn, N. Y.; Casper, Wyo.; and East Providence, R. I. The company has 6 refineries in Europe.

E. L. Sinclair has been designated by Socony Mobil as the official Sustaining Member representative.

American Messer New Sustaining Member

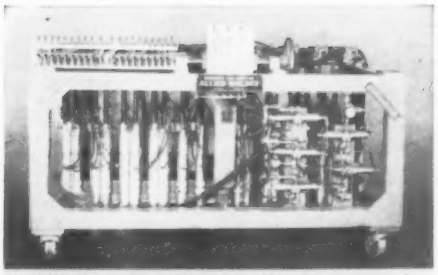
The firm of American Messer Corp., 405 Lexington Ave., New York 17, N. Y., has been added to the increasing number of Sustaining Members of the AMERICAN WELDING SOCIETY.

American Messer Corp. is an American firm affiliated with Adolf Messer, GmbH, Frankfurt am Main, Germany. The Messer firm has been active in the field of welding and cutting machines for over a half century and has been active in the United States for most of these years.

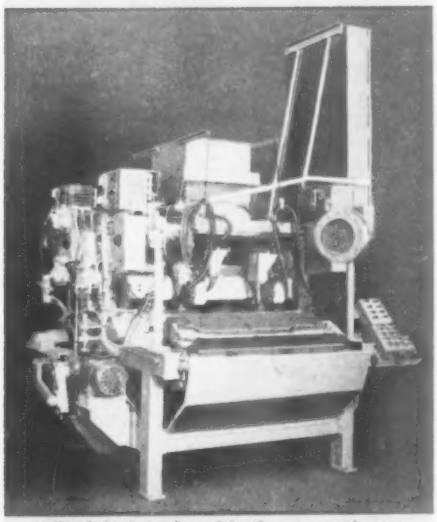
American Messer Corp. now offers American industry a complete line of hand and automatic cutting machines. These include a new sine-cosine machine, the Sicomat, with electric eye control, employing a new position drive principle which insures accurate electronic following independent of the number of torches or drive obstructions, and further, permits the electronic following of $^1/_{10}$ scale drawings from a remote location.

In addition to cutting machines, Messer fabricates plants to produce oxygen, argon and nitrogen as gaseous or liquid products. These plants range in size from 5 to 150 tons/day oxygen capacity.

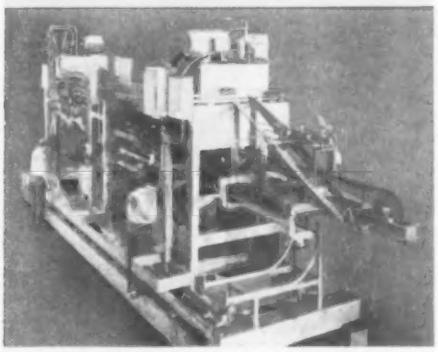
The Sustaining Member representative is E. A. Johnson, Jr.



Allied designed and built air operated machine for drilling 20 holes simultaneously in trailer floor.



Allied designed and built automatic over and under arc welder. Welds automotive frame X member.



Allied designed and built automatic two-stage resistance welder with transfer and turn over devices. Welds radiator support assembly.

how big is your problem . . .

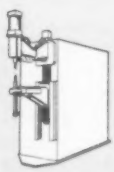
Really?

If it involves special equipment for a production welding operation it may not be a problem at all—just an assignment when placed in competent hands.

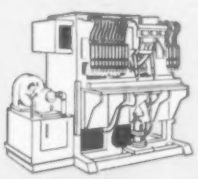
This is our kind of work – we specialize in it – do it every day; designing and building special machines for welding everything from bathtubs to trailers, frequently including provisions for automatic handling and transfer where the job is a part of a production line set-up.

We're no brain trust here at Allied Welder, but we keep some awfully important production people happy with our creative designing and manufacturing know-how, delivery, too.

May we work with you on your next job?

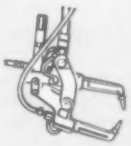


Standard Welders



Special Welders

Automation Equipment



Automatic Arc Welders

Welding Guns

ALLIED WELDER CORPORATION

8700 BRANDT DEARBORN, MICHIGAN

Creative Design

For more details, circle No. 14 on Reader Information Card

THINGS YOU SHOULD KNOW

(That Happened in July)

• President D. F. Ellis of The Australian Institute of Welding visited with AWS President C. P. Sander and your Secretary here in New York during July. Mr. Ellis, who is associated with a manufacturer of welding supplies in Australia, inspected plants of several manufacturers and fabricators in the United States.

• On July 15th your Exposition Committee, with T. S. Long as Chairman and with President Sander in attendance, met in New York to reconsider possible sites for the 1959 Exposition and Annual Meeting, which had been tentatively planned for Buffalo. Following a thorough study of the relative advantages of available sites it was voted to hold the 1959 activities in Chicago from April 6th to 10th. It was further agreed to hold the 1960 Exposition and Annual Meeting in Los Angeles from March 28th to April 1st.

• Your Technical Division has published new Filler Metal Comparison Charts. These are designed to answer such questions as: (1) what classification is Brand X?; (2) is Brand X the same classification as Brand Y?; (3) who makes it and distributes it? We believe this to be the most comprehensive group of charts available showing the AWS-ASTM classifications and the filler metals.

• The first section of the Fourth Edition of the Handbook is now in the hands of the printer and should be available for distribution when you read this.

• Elsewhere in this copy of THE WELDING JOURNAL you will find an article "The Welding Qualification Problem" which is the result of several years of committee work and gives a history of the problem, a proposal and an explanation of the various factors. Read this and send your comments to our Technical Secretary.

• H. F. Reinhard, Chairman of your Public Relations Committee, has acted promptly and effectively on two or more occasions this summer to alert all interested groups concerning proposed state laws dealing with the regulation of welders or welding.

• President C. P. Sander has scheduled the next meeting of your Board of Directors for November 7th in Hotel Sherman, Chicago. During this week the American Society for Metals will be holding its annual meeting, the Metals Show and the Second World Metallurgical Congress. An AWS committee is planning three panel sessions, to be held November 4th and 5th, on "Ship Welding," "Electrodes" and "Stress Relieving and Preheating" with one-half of the panel members representing foreign countries. On November 6th the AEC Welding Committee will hold open sessions on "Welding of Stabilized 18-8 Stainless Steel" and "Welding of Rare Metals." A general session on "Automatic Welding" may be held on November 5th. It is probable that other AWS committees will hold meetings in Chicago at this time.

• John Blankenbuehler and members of his Member Classes Committee are studying problems involved with the establishment of a professional membership to be known as "Welding Engineer" or "Fellow." They are also considering a "Welding Operator" membership. They would welcome your suggestions concerning these or other membership classifications.

• H. A. Sosnin and Prof. R. C. Wiley, who are both very active in connection with our education committees, spent July 25th at Headquarters, and met with EAC chairman C. E. Jackson and others in Philadelphia on July 30th.

Fred L. Plummer

EAC DOINGS

Chairman's Review of EAC Progress

by Clarence E. Jackson

As it enters its second year, the Educational Activities Committee has completed a preparatory period in which many surveys and investigations have been conducted into the many fields of welding education. All of these investigations and surveys have led to one conclusion—the vital need for welding education in all branches of engineering.

There is not a single level upon which welding education can be considered adequate.

Despite the seriousness of this situation, we are happy to have evolved something concrete out of what at first appeared to be an almost hopeless educational situation. We have reached a stage where, having surveyed the field, we are in a position to advise courses of action and also to implement these actions.

Having reached this stage, it is necessary to coordinate the actions of our committees and to use the facilities at headquarters to open up our lines of communication. We have secured the services of Arthur L. Phillips, at national headquarters, who will act as Secretary to EAC and liaison between EAC, the committees and headquarters.

It is vitally necessary to have someone at headquarters to whom all the information can be channeled and who, being in touch with SOCIETY policy at all times, can advise upon policy matters which are bound to crop up in these varied activities.

Eight committees have been appointed and these will form the nucleus of many more committees and task forces which will be needed to explore the many facets of education in the metal-joining field.

In the sections a great deal of educational activity is apparent. An educational representative has been appointed by most of the sections throughout the country. This is a big step forward. It provides an avenue of communication for each section. Both the section and ourselves can be advised upon what is needed and what will have to be done to provide the education required in a particular area. This information, channeled through EAC, is going to be a very fruitful source of ideas. It will help in the preparation of material which

Clarence E. Jackson, Chairman, Educational Activities Committee; Research Metallurgist, Linde Co., Newark, N. J.

NEW Airco POP can seals out dampness...

keeps stainless steel electrodes "oven fresh" in re-usable aluminum container — eliminates special storage facilities!

Airco Stainless Steel Electrodes are now packed in seamless aluminum containers. Each "POP" can contains 10 pounds of electrodes, and is sealed with a waterproof airtight industrial tape.

This hermetic electrode packaging technique is the best way to keep stainless steel electrodes "oven fresh"—without benefit of special shop or field storage equipment. Unused electrodes can be kept fresh by resealing the can.

Airco Stainless Steel Electrodes, in the "POP" can, are but one of many types in Airco's complete line that also includes hard-facing, cast iron, mild steel, general, and special purpose electrodes. Send for the free Airco Electrode Guide which will help you select the right electrode for your special job.

AT THE FRONTIERS OF welding PROGRESS YOU'LL FIND . . .

AIRCO

Offices and dealers in most principal cities

AIR REDUCTION SALES COMPANY

A division of Air Reduction Company, Incorporated
150 East 42nd Street, New York 17, N. Y.

On the west coast — Air Reduction Pacific Company
Internationally — Airco Company International
In Cuba — Cuban Air Products Corporation
In Canada — Air Reduction Canada Limited

Products of the divisions of Air Reduction Company, Incorporated, include: **AIRCO** — industrial gases, welding and cutting equipment, and acetylenic chemicals • **PURECO** — carbon dioxide — gaseous, liquid, solid ("DRY-ICE") • **OHIO** — medical gases and hospital equipment • **NATIONAL CARBIDE** — pipeline acetylene and calcium carbide • **COLTON** — polyvinyl acetate, alcohols, and other synthetic resins.

For more details, circle No. 15 on Reader Information Card

For flawless high strength weld metal in missile components

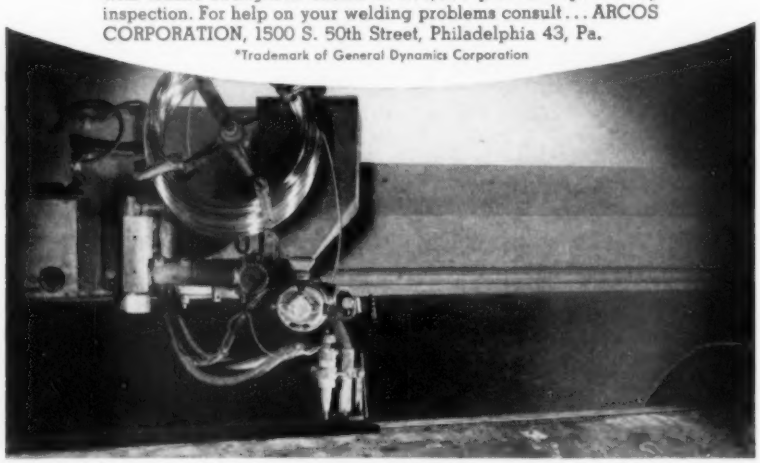
Job Report Courtesy of
Research Welding & Engineering Co., Inc., Compton, California

WELD WITH ARCOS

CHROMENAR Spooled Wire

Light weight was important in this welded missile component that was required to hold air under 3,000 p.s.i. pressure. After making the root pass weld with the Arcos EB* consumable insert, the weld was completed by submerged arc welding with Arcos CHROMENAR CMV welding quality wire. CHROMENAR CMV was selected because its weld metal could be heat treated to match the base metal with tensile strength in excess of 200,000 p.s.i. and pass x-ray inspection. For help on your welding problems consult... ARCOS CORPORATION, 1500 S. 50th Street, Philadelphia 43, Pa.

*Trademark of General Dynamics Corporation



For more details, circle No. 16 on Reader Information Card

will be of inestimable benefit to other sections and to the AWS membership as a whole.

Course Outlines

One of the many ways in which our committees are dealing with the problem of education is in the preparation of course outlines. There is no doubt whatever that a need exists for courses on specific aspects of welding. These courses eventually should embrace every facet of welding, both practical and theoretical. This is a long way off but is a major objective of EAC. The outlines that have been and are being prepared at the moment are intended to act as a guide to speakers. The outline covers the complete subject and the speaker merely discusses the various subheads.

One section is going to test these out this year, starting in September. Not only are they appointing speakers to give talks based upon the outlines but they are having the talks tape recorded. Later these tape recordings will be transcribed. The transcriptions will be sent to EAC for comments and EAC will turn them over to the Secretary for editing. It is the intention of EAC to have each transcription, after editing, checked by a number of experts on the subject covered. These experts will check the material for technical accuracy and will also indicate where additional coverage is necessary.

By this means we anticipate having a most comprehensive, accurate and, what may turn out to be, the most complete course upon the particular subject ever produced.

The far-range objective is to compile courses of all of these subjects, embracing every facet of welding, and to make them available to every section. In the educational field the Philadelphia chapter of the AWS has announced a course in the Principles of Welding Engineering and one in the Elements of Welding Metallurgy which are to be held at the Drexel Evening College beginning September 24th and continuing through June 17, 1958.

The Philadelphia branch is to be congratulated! We know that other sections are providing similar courses. It will not be long before many more sections are providing educational courses, either given through the medium of local colleges or sponsored or arranged by local sections.

The EAC can accomplish its objectives only with the help of the members of the AWS. The help, advice and enthusiasm of the sections and their educational representatives will be vitally necessary if this program is to be successful.

In-Plant Training

A most comprehensive outline for an

in-plant training program has been prepared by this committee.

This tentative outline is slanted toward designers, inspectors and supervisors. An idea of the comprehensive nature of this may be gathered by a list of the main headings. It should be noted that each of these main headings is capable of being expanded to any desired length based upon the particular needs of the plant carrying out the program.

The main headings are: Orientation; Welding Terms and Definitions; Welding and Allied Processes; Basic Metallurgy; Weldability of Metals; Welding Design; Specifications; Qualifications; Inspection, Test and Quality Control; Safe Practices in Welding; Review.

A great deal of work has been expended on this outline and much has still to be done. It is an indication of the activity of this particular committee and signifies its approach to an industrial problem which has long been apparent.

Apprentice Training

Excellent work has been done in the field of apprentice training. Initial activities have been with the pipefitters. Work is planned with the iron workers, boilermakers and other crafts. Working on the general assumption that welding is required in all fields of metal working, it became obvious that all apprentices in these fields should be given a grounding in welding. A course given in August at the Purdue University was to instruct teachers of apprentices in the various types of welding. Experts in each field of welding, the services of whom were kindly contributed by industry, actually demonstrated the process they discussed.

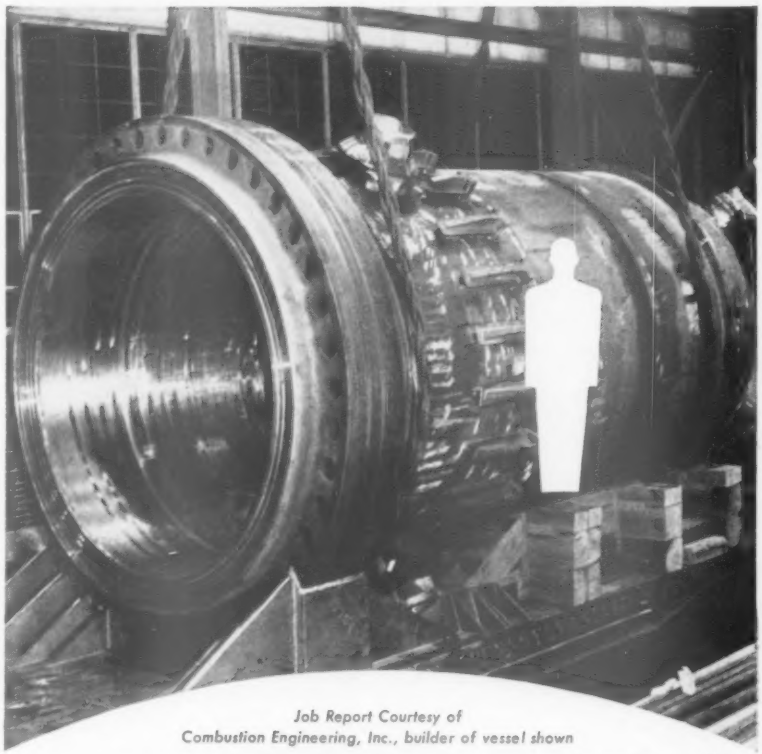
This course at Purdue University is to be the subject of "EAC Doings" in a forthcoming issue of THE WELDING JOURNAL. It should be mentioned, however, that these teachers will reach approximately 20,000 apprentices in the United States and Canada.

Visual Aids

In all educational activities there is one common need—visual aids. Today, more than ever, it has been found that visual presentations assist greatly in the assimilation of any knowledge, technical or otherwise. The Visual Aids Committee of the EAC is concerned with the preparation of such material.

A report is being prepared, upon a proposed motion picture, which will indicate the various branches of the welding industry which could be featured. It is the intention of this committee to survey the field and incorporate in this report what would be needed in such a film and the group to which the film should be directed. It is no more possible to reach a number of groups

This WELDED nuclear pressure vessel holds a practical idea for you

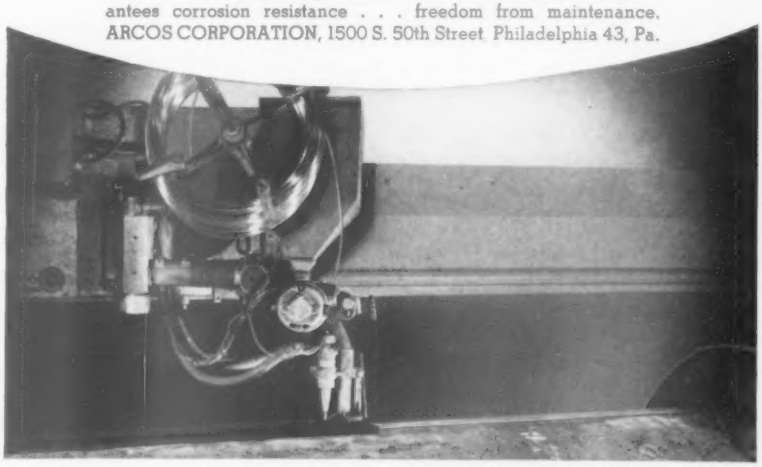


Job Report Courtesy of
Combustion Engineering, Inc., builder of vessel shown

USE ARCOSITE FLUX

for submerged arc welding

In nuclear installations where radio activity makes weld failure dangerous to personnel and can cause indefinite shutdown, sound corrosion resistant welds are of utmost importance. To inhibit corrosion, portions of the 9 ft. dia. interior of this 33 ft. reactor were overlaid with ¼ in. of 308L weld metal. Submerged arc welding with ARCOSITE S4 flux was used for the job. The girth and longitudinal joints of the low alloy steel plates were also submerged arc welded using ARCOSITE B5 flux. Cost-wise, no other conventional method of cladding was practical. Arcos weld metal quality guarantees corrosion resistance . . . freedom from maintenance. ARCOS CORPORATION, 1500 S. 50th Street Philadelphia 43, Pa.



For more details, circle No. 17 on Reader Information Card

2 RESEARCH METALLURGISTS

With BS or MS degrees. One position is for a recent graduate. The other is for a man up to 35, with experience in the application of metallurgy to production problems.

Work in applied research, dealing with welding ferrous and non-ferrous alloys, investigation of service problems, and selection of materials of construction.

C F BRAUN & CO
Alhambra, California
Engineers and Constructors

simultaneously with a motion picture than it is with a lecture. It will be necessary, therefore, to decide to which group the first film should be directed. Subsequent films could reach the other groups. When the report is complete, it will be submitted to the Technical Council for further action.

College Training

It is becoming more and more obvious that an engineer can hardly be regarded as fully trained until he has learned the rudiments of welding. Metal joining has become such an essential part of our life today that a knowledge of its fundamentals is needed by practically all branches of engineering.

A symposium on education was held in Philadelphia in April of this year in which some very interesting facts were disclosed. A tape recording was made of this symposium and we hope to have available in the near future a small brochure which will give an almost verbatim report of the proceedings.

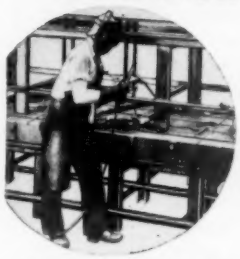
The foregoing indicates what the EAC and its subcommittees have been doing during the spring and summer. We are all looking forward to increased activity during the fall which will produce concrete results. We need your help if we are to have something concrete to show for our work, something which will aid welding, welders, technicians and engineers in their never-ceasing objective of finding better, safer, faster, more reliable and more economical means of metal joining.

EMPLOYMENT SERVICE BULLETIN

Positions Vacant

Excellent opportunity for young engineer to join national staff of American Welding Society in New York City. Recent promotion creates vacancy for assistant to technical secretary. Responsibilities to include representation on technical committees, research on technical data, editing of standards, answering technical inquiries from industry. Applicant must have degree in engineering, with at least three years experience, preferably in welding or allied fields. Salary commensurate with qualifications and experience. Send résumés to Technical Secretary, 33 W. 39th St., New York 18, N. Y. All replies will be held in confidence.

OPEN UP NEW OPPORTUNITIES



BY MEETING THE GROWING DEMAND FOR

PRECISION WELDING

Precision Welding can offer a savings over other methods of assembly, broaden your operation cut costs, increase profits. The ideal unit for this type work is the Challenge Precision Welding Table. It's suitable for layout work, "tack" welding and final welding operations. T-slots permit accurate positioning and holding of the work. Made of a special analysis semi-steel, designed to withstand the welding flame or arc. Guaranteed accurate to within .002". Available in three sizes.

SE-113

Challenge
TRADE-MARK ®

The Challenge Machinery Co. Dept. WJ-9
Grand Haven, Michigan

Please send complete information on Challenge Welding Tables and other Precision Surface Equipment.

Name_____

Company_____

Address_____

Circle No. 18 on Reader Information Card

Services Available

A-698. Young college man, 19, studying for ME degree, but seeking to specialize in welding engineering field, desires position as welding laboratory assistant or welding shop helper with organization in New York-New Jersey metropolitan area for period September 1957 through January 1958. Must return to college in February to complete freshman term, but is available for re-employment during summer vacation. Would prefer position leading to possible permanent connection after graduation.

WANTED
WELDING ENGINEER
Work In Southern California

Fifty-five year old Los Angeles manufacturing firm has permanent position for a welding engineer (quality control) with metallurgical background; degree desirable. Must be capable of developing and writing welding procedures and techniques in stainless steel and aluminum; ability to carry full responsibility for all welding operations.

Give job history, brief biographical account. Include photo.

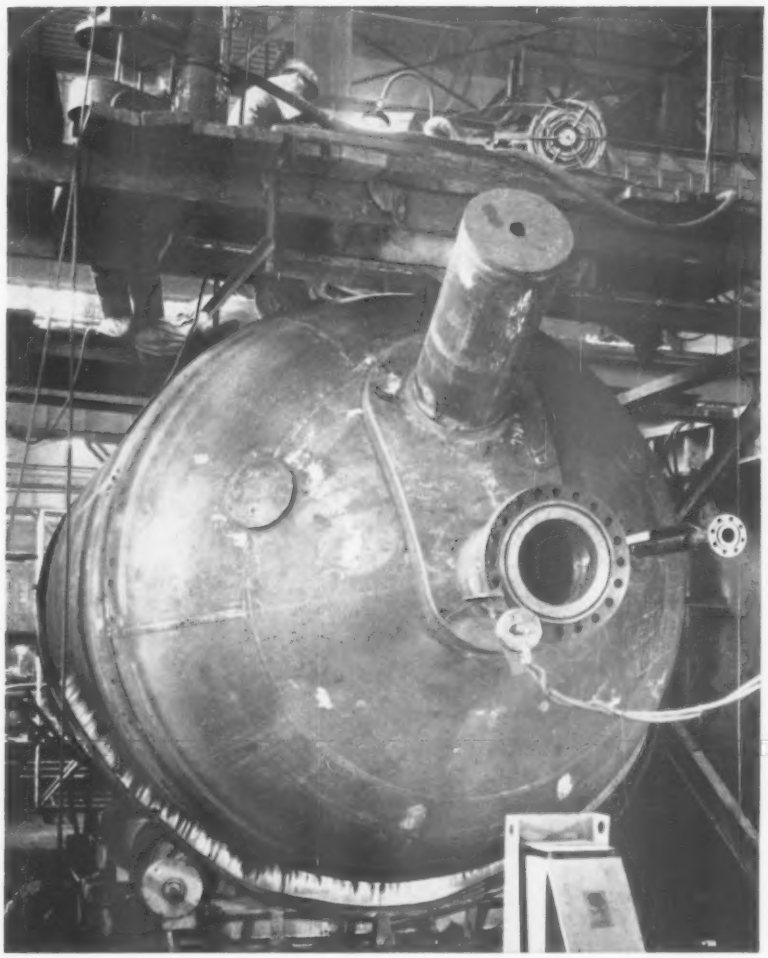
STANDARD STEEL CORPORATION
5001 S. Boyle Ave.
Los Angeles 58, Calif.

WELDING DEVELOPMENT ENGINEERS

A new welding laboratory and our expanding development program to accommodate a wide variety of diversified product lines necessitates increasing our present staff. Engineers interested in welding development and having up to 10 years experience are needed. Excellent employee benefits.

Send detailed resume and salary requirements to:

ALCO PRODUCTS, INC.
Employee Services Department
Schenectady 5, New York



When fabrication codes demand 100% X-ray inspection...

SPECIFY *Drawalloy* CORPORATION

Stainless Steel Welding Wire

In hundreds of applications, *Drawalloy* wire has been put to the test . . . X-ray, dye check, pressure and service and with the same consistent result—OK as welded. That's why Frank Iapalucci, Manager of Welding Engineering for Baldwin Lima Hamilton, Eddystone, Penna., selected *Drawalloy* chrome-moly wire for the automatic welds on this reactor. The vessel is constructed of A 301-54T Grade B firebox quality steel ranging in thickness from 5-1/16" to 2-5/8". *Drawalloy* 1-1/4 Cr, 1/2 Mo wire was used for all submerged arc joints.

When inspection by X-ray is required, don't gamble . . . rewelding is expensive . . . specify Drawalloy "quality controlled" wire. *Drawalloy* stainless steel welding wire is produced to strictly controlled specifications to provide the right chemistry, finish and temper for smooth operation in your equipment and to provide X-ray quality welds.

Why not discuss your stainless welding wire needs with your *Drawalloy* Distributor or Representative . . . a man ready to help you. Bulletin 355-DC provides complete information on every grade of *Drawalloy* wire. Write to: Drawalloy Corporation, Lincoln Highway West at Alloy Street, York 13, Pennsylvania.

DRAWALLOY
CORPORATION
YORK, PENNSYLVANIA

THE WIRE MILL FOR THE WELDING INDUSTRY — STAINLESS STEEL · HARD SURFACING · TOOL STEEL

For more details, circle No. 19 on Reader Information Card

Section News and Events

as reported to Catherine O'Leary

ANNUAL GOLF PARTY

Itasca, Ill.—153 members of the *Chicago* Section took part in the Annual Golf Party held on June 8th at the Nordic Hills Country Club in Itasca. The event this year was restricted to members only in an attempt to generate good fellowship in the local group.

Dinner was served in the form of a smorgasbord which was highly acceptable to the hungry golfers.

The day was perfect for golfing and other outdoor activities and everyone had an enjoyable time as evidenced by their enthusiasm.

"Everyone went home with a prize."

18TH ANNUAL SYMPOSIUM

Cleveland, Ohio.—On May 10, 1957, the *Cleveland* Section held their 18th Annual Symposium at the Manger Hotel. This symposium was dedicated to A. F. Davis, "in gratitude and recognition for his devoted service as one of the Section's founders, past chairman, ardent worker on innumerable committees, and loyal charter member; for his service as a national director; and for his 43 years of front-line duty as champion of the cause of arc welding."

The program opened at 10:30 A.M. with registration on the mezzanine of the Hotel. Educational exhibits were held in the Chester Room from 11 A.M. to 6 P.M. and were very well attended.

About 200 were present at the technical session held in the afternoon. Three outstanding papers were presented by the following: Prof. Roy B. McCauley AWS, chairman of the Welding Engineering Department of Ohio State University, whose subject was "Education for Welding"; John Mikulak AWS, assistant to the vice-president in charge of manufacturing, Worthington Corp., spoke on "Design for Welding"; Roger W. Clark AWS, consultant on metal joining processes in the General Engineering Laboratory of General Electric Co., discussed the "Application of Non-Destructive Testing Methods."

The largest attendance—over 600—turned out for the dinner held in the

SECTION MEETING CALENDAR

SEPTEMBER 6

NORTH CENTRAL OHIO Section. Plant Visit. Galion Iron Works, Galion, Ohio. Dinner and Get-acquainted meeting at the Fairway Club.

SEPTEMBER 9

NORTHWEST Section. Minneapolis, Minn. Elks Club. Happy Half Hour 6:00 to 6:30 P.M. Dinner 6:30 P.M. "Basic Metallurgy," Norman C. Qualey, Northern Ordnance, Mc.

SEPTEMBER 13

DETROIT Section. Dinner 6:30 P.M. Meeting 8:00 P.M. Engineering Society of Detroit. Arc Welding. Representative of Linde Company will describe their "Unionarc" process.

SEPTEMBER 16

PHILADELPHIA Section. Dinner at Kavanaugh's Restaurant 6:15 P.M. Educational meeting at The Drexel Institute of Technology, 8:00 P.M. "Welding the Steels of Tomorrow," George E. Linnert, Armco Steel Corp.

SEPTEMBER 17

TOLEDO Section. Dinner 6:30 P.M. Meeting 8:00 P.M. Maumee River Yacht Club, Toledo, Ohio. "Aluminum and Magnesium Welding."

SEPTEMBER 18

PEORIA Section. Dinner 6:30 P.M. Meeting 7:45 P.M. Mecca Supper Club, Farmington Road, Peoria, Ill. "The Latest Improvements on Resistance Welding Application and How It Affects Design and Application," Bob McDonald, Precision Welder & Flexopress Corp.

SEPTEMBER 19

MICHIANA Section. South Bend, Ind. "Tool and Die Welding," representative of Welding Equipment and Supply Co.

SEPTEMBER 20

PITTSBURGH Section. Plant Visit. Pullman-Standard Car Mfg. Co., Butler, Pa. Buffet lunch at 12:30 P.M. in Company Cafeteria.

SEPTEMBER 21

MARYLAND Section. Baltimore, Md. 9:00 A.M. Tour of Baltimore Harbor Tunnel Project. Start at the Fairfield Ventilating Building.

SEPTEMBER 24

OLEAN AND BRADFORD Section. 7:00 P.M. Emery Hotel, Bradford, Pa. "Joining Atom Reactor Metals," Herbert S. Kalish, Sylvania Corning Nuclear Corp.

OCTOBER 4

PHILADELPHIA Section. 7:45 P.M. Engineers Club, 1317 Spruce St., Philadelphia, Pa. Panel Discussion, "Processes for Cutting and Gouging of Metals and Alloys."

OCTOBER 11

DETROIT Section. Dinner 6:30 P.M. Meeting 8:00 P.M. Engineering Society of Detroit. "Application of Static Controls," Jerry Kommendera, Valve Air Corp. in conjunction with National Electric Welder and Westinghouse.

OCTOBER 14

NORTHWEST Section. Minneapolis, Minn. Elks Club. Happy Half Hour 6:00 to 6:30 P.M. Dinner 6:30 P.M. "Aluminum—Analysis and Application," Vic McChesney, and Howard Adkins, Kaiser Aluminum.

OCTOBER 15

TOLEDO Section. Plant tour through new SOHIO Refinery.

OCTOBER 16

PITTSBURGH Section. 8:00 P.M. Auditorium of Mellon Institute of Industrial Research, (Oakland) Pittsburgh, Pa. "How to Meet Welding Code Requirements," E. C. Korton, Hartford Steam Boiler Insp. & Ins. Co., and R. W. Arner, Pennsylvania State Highway Department.

OCTOBER 17

MICHIANA Section. Plant visit. Tentative—Pullman Standard Car Mfg. Co., Michigan City, Ind.

OCTOBER 21

PHILADELPHIA Section. Engineers Club. 8:00 P.M. "New Equipment and Applications of Welding Processes to High Temperature Alloys," by Gordon Parks, Solar Aircraft Co.

OCTOBER 22

OLEAN AND BRADFORD Section. 7:00 P.M. Castle Restaurant, Olean, N.Y. "Welding of Clad Steels," Louis K. Keay, Lukens Steel Co.

Editor's Note: Notices for December 1957 meetings must reach Journal office prior to October 1, so that they may be published in November Calendar. Give full information concerning time, place, topic and speaker for each meeting.

More welders use more Sylvania Electrodes

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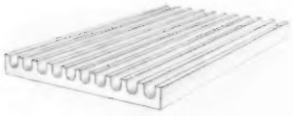

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GOLF PARTY HELD BY CHICAGO SECTION ON JUNE 8

At the starter's shanty are R. J. Burns, J. K. Calhoun, A. G. Craske, C. M. Wigley and Carl Saks

At the 10th hole takeoff are, left to right, B. G. Ward, A. F. Chouinard, W. G. Bergmann and M. A. Tylutki

Main Ballroom. Toastmaster was Bill Gordon, named No. 1 radio entertainer in the Forest City by the local chapter of the American Federation of Radio and Television Artists. Featured speaker was Oliver P. Bolton, newly appointed Director of Commerce for the State of Ohio. Mr. Bolton spoke on "The Independent: Cause of Crisis."

ANNUAL REUNION NIGHT

Huntington Park, Calif.—The *Los Angeles* Section held their 13th Annual Reunion Night on Thursday, June 20th with 114 members and guests present.

This meeting, the final one of the fiscal year, is held in honor of their many fine past chairmen and is traditionally a night of informality and a departure from the technical aspects of welding.

Featured festivities for the evening were a delicious "Rib" barbecue and music by "Trudy" Hartman, accor-

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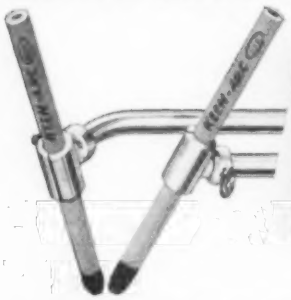

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Albert Imburgia, Welding Engineer, explains attachment welding detail on underside of reactor. Plate material is A301-54T-Gr. B firebox quality steel. Fittings are A 301-54T-Gr. B, A 335-53T-Gr. P12, A 182-53T-Gr. F12. Thicknesses ranged from 2-5/8" to 5-1/16".

100% X-ray sound with no rewelding is a common occurrence on Atom•Arc applications. It's also a common occurrence to find the country's leading fabricators switching to Atom•Arc electrodes for welding jobs involving mild and low alloy steels. One such company is the Baldwin-Lima-Hamilton Corp. of Eddystone, Penna.

Frank Iapalucci, Manager of Welding Engineering, and Carl Ascenzi, Chief Welding Engineer, have developed at Baldwin a quality control program for weldments that demands the ultimate in performance for every electrode used in their shops. Atom•Arc 8016 CM electrodes were their choice for all hand welds on this reactor for a large eastern refinery. The X-ray results proved their judgment sound.

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Atom•Arc electrodes will provide X-ray quality weld metal and greater joint efficiency, at a lower cost, on a wider range of ASTM steels than any other single group of electrodes. Atom•Arc electrodes are available in the following AWS grades: E7016, E7016 A-1, E8016 C-2, E8016 B-2, E9016 B-3, E10016 (1.70% Mn, .40% Mo), E12016 (1.9% Ni, .9% Mo, .2% V) and Atom•Arc T (E11016) for welding T 1 steel.

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DAVIS HONORED BY CLEVELAND SECTION

The 18th annual symposium sponsored by the Cleveland Section was dedicated to A. F. "Charlie" Davis, vice-president of the Lincoln Electric Co. Here Mr. Davis, extreme left, is being greeted by Chairman A. G. Portz and featured speaker O. P. Bolton

dionist.

The meeting and barbecue were held in the open air patio of the Elks Lodge in Huntington Park, under ideal weather conditions. After cocktails, dinner and the drawing of door prizes, Chairman C. B. Smith introduced the newly elected officers as follows: chairman, D. P. O'Connor, Los Angeles Water & Power; vice-chairman, John Ross, American Platinum Works; secretary, Dick Hayes, Pacific Metals Co. Mr. O'Connor presided for the balance of the evening and called upon Leo West, Douglas Aircraft Co., Long Beach Division, the newly appointed chairman of the Aircraft and Rocketry Panel, who in turn introduced the new Aircraft and Rocketry Panel officers as follows: Howard Eubanks, Convair, vice-chairman; Bruce Baird, North American Aviation, secretary; and Leonard Buchanan, Air Reduction Pacific Co., membership chairman.

The retiring section chairman, Chas. Smith, was presented with a set of folding TV tables, in behalf of his fine cooperation and support.

National President C. P. Sander completed the ceremonies by presenting the retiring chairman with his past chairman's pin. Upon conclusion of the meeting, all the outgoing and incoming officers and past chairmen received a fine round of applause in recognition of their accomplishments during the year.

FIELD TRIP

Napa, Calif.—The Kaiser Steel Corp. was host for the annual field trip of the *San Francisco* Section on May 27th. At the luncheon preceding the inspection, new officers were installed and presentation of the Society's Meritorious Certificate was made to Dr. Paul DeGarmo of the University of California, Berkeley.

LOS ANGELES SECTION HOLDS ANNUAL REUNION NIGHT ON JUNE 20

Caught between two fellow members of the Los Angeles Section are Bruce Baird and Leo West

Walter Tenner, George Murphy and Ben Gray enjoying the "rib" barbecue

Past Section Chairman Al Fenlason and AWS President C. P. Sander are entertained by "Trudy" Hartman

New chairman D. P. O'Connor takes over while Dick Hayes, Herb Clemens and out-going chairman C. B. Smith look on

President Sander presenting Mr. Smith with past chairman's pin. Mr. Clemens and Mr. O'Connor look on

SAN FRANCISCO SECTION VISITS KAISER STEEL PLANT

On May 27th the San Francisco Section visited the Kaiser Steel Corp. plant at Napa, Calif. Here the members and guests are assembled in front of Personnel Building

Past chairman Larry Kech, outgoing chairman Fred Stettner and incoming chairman Stan Roberts inspect inside weld seam of 30-in. diam HPI high-test line pipe

Guest speaker E. Paul DeGarmo being presented the Meritorious Certificate by District Director Charles Robinson. Back row, left to right, Bill Ajello, Mr. Stettner, Prof. DeGarmo and Mr. Robinson. Front row, left to right, Barney Fass, Mr. Roberts, Cecil Dogett and Mr. Kech

Touring the Napa Fabricating Division of the Kaiser Steel Corp., the 110 members and guests observed the fabrication of water well casing, a range of pressure vessels up to large refinery equipment, penstocks, large mill-type cranes, barges and other types of plate fabrication. They also visited the pipe shops where thousands of miles of large diameter API line pipe is continuously produced by submerged-arc and electric-resistance welding.

Members were particularly interested in the adaptation to mechanization of different types of welding equipment for special applications. The variety of work in process gave visitors the opportunity to observe several methods of shop approaches to production welding and there was universal agreement that this had made the trip a most rewarding experience.

SUMMER MEETING

Miami, Fla.—The second summer meeting of the *South Florida* Section was held on Wednesday, July 17th, at the new meeting hall, Miami Firemen's Benevolent Association. Meeting was called to order by Chairman Herbert Hoodwin at 8:05 P.M.

Following a business session at which plans for the coming year were discussed in detail, the meeting was turned over to Program Chairman Perry Kennerk, who showed a thirty-minute film, entitled "Petrified Rivers, Story on Uranium." This film was secured from the Union Carbide Corp.

The pleasant social get-together which followed was adjourned at 11:00 P.M.

MEETING DATE

Washington, D. C.—The *Washington* Section, in a resolution adopted by its Executive Committee, has changed its monthly technical meeting date from the second Tuesday to the second Friday of each month, commencing with its first meeting on Friday, Sept. 13, 1957 and continuing through the 1957–58 season.

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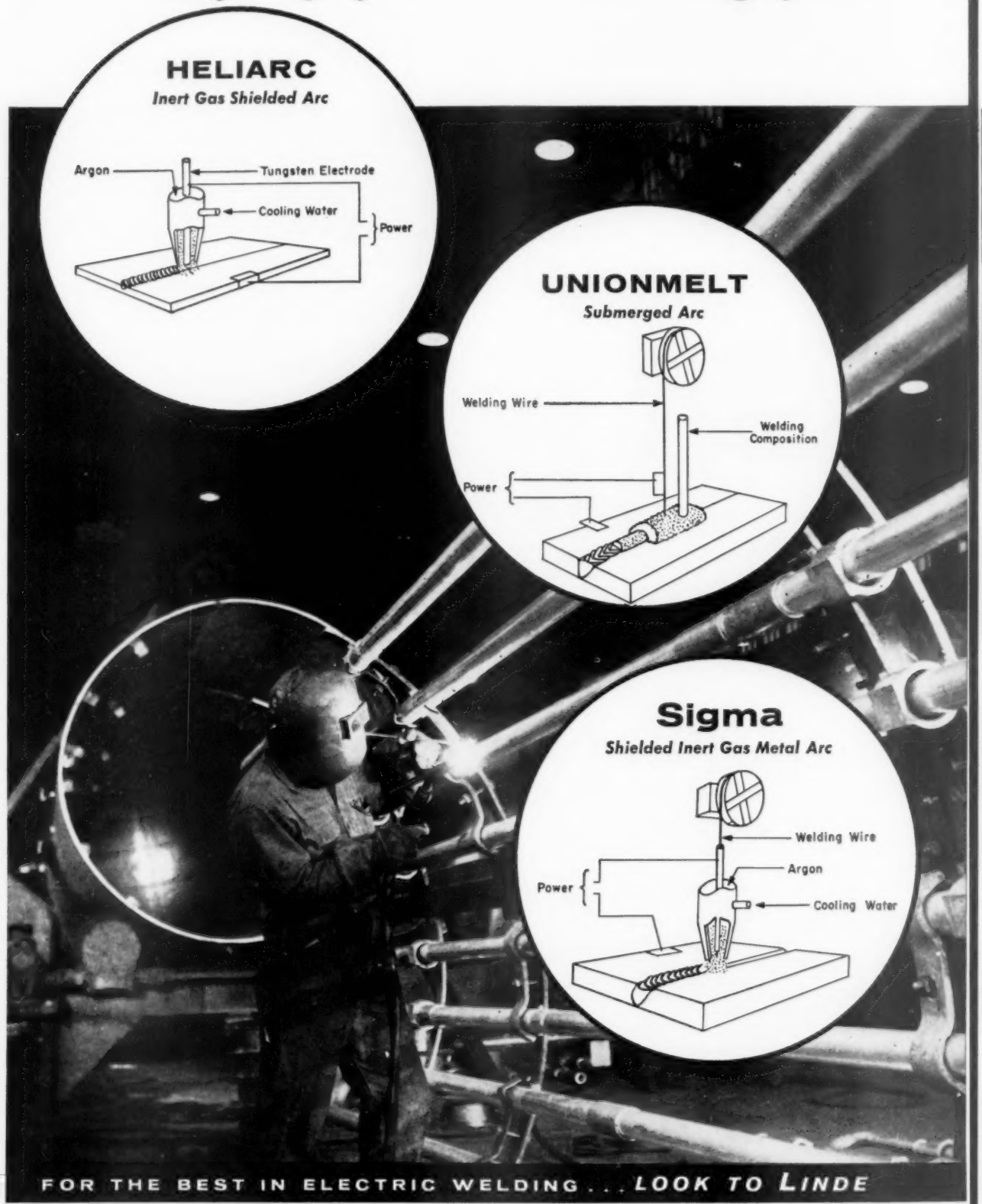

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Inert gas shielded arc welding—

HELIARC Apparatus for inert gas shielded arc welding, using a tungsten electrode and a shield of LINDE argon, is tops for joining hard-to-weld commercial metals. On stainless steel and aluminum, HELIARC Welding is fast and clean, producing high-quality welds that resist corrosion. HELIARC Welding eliminates costly grinding and finishing, making it a valuable method for quantity production of hard-to-weld metals.

Submerged arc welding—

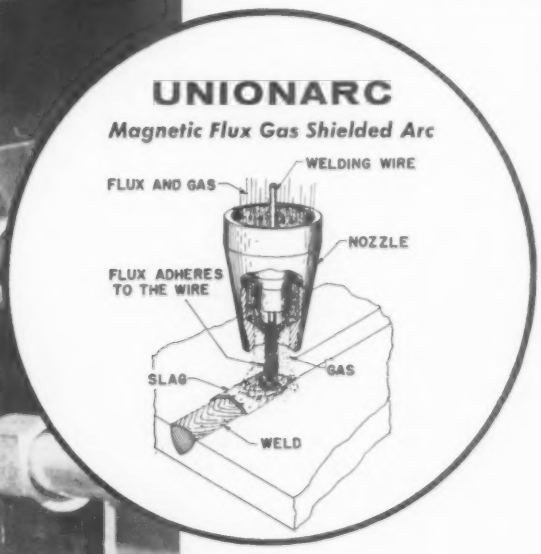
Shapes made of materials ranging from light gage to heavy plate, adaptable to mechanization, can be most economically joined by UNIONMELT Welding. It is used on low and medium carbon steels and alloy steels, including those containing chrome and/or nickel. UNIONMELT Welding is also used extensively for resurfacing metal, providing extra wear and corrosion resistance. UNIONMELT Welding is fast and inexpensive on production jobs.

Shielded inert gas metal arc welding—

One of the most versatile welding methods is Sigma Welding. LINDE's Sigma apparatus, using a shield of LINDE argon, is ideal for manual welding of commercial metals $\frac{1}{8}$ in. or more thick, and for automatic operation on lighter gage metals to .050 in. Highest quality welds can be made on aluminum thicker than $\frac{1}{8}$ in. at speeds up to 16 inches per minute. Build-up and surfacing jobs are also improved by using LINDE's Sigma welding method.

New! Magnetic flux gas shielded arc welding—

UNIONARC Welding, LINDE's most recent development in electric welding, is an extremely fast method for welding mild steel. This method employs a continuously-fed, bare steel wire electrode, magnetically coated with flux conveyed in a stream of carbon dioxide shielding gas. Manual welds can be made easily in any position—vertical, overhead, downhand—with no stops to change electrodes. The speed, versatility, and ease of operation of of UNIONARC Welding brings costs down 25% to 65% below those of manual covered electrode welding. Clean, smooth, high-quality welds are provided, even in the presence of moderate amounts of rust, scale, and moisture.



Engineers at LINDE have been designing, developing, and testing electric welding methods and apparatus for many years. Help on any welding method is yours for the asking. You can improve your work and cut production problems by taking advantage of LINDE's experience. For data on UNIONARC Welding or any other electric welding method, call the LINDE office nearest you.

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New Members

Effective July 1, 1957

MEMBERSHIP CLASSIFICATION

A—Sustaining Member B—Member C—Associate Member
D—Student Member E—Honorary Member F—Life Member

Total National Membership

Sustaining Members	172
Members	6,096
Associate Members	6,406
Student Members	164
Honorary Members	9
Life Members	15
Total	**12,862**

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Jay, Glenn A. (C)

ARIZONA
Aspey, F. Morris (B)

BOSTON
Romaniuk, Michael J. (B)

CANADA
Haimerl, Duncan Alois (C)

CHICAGO
Adelsperger, Fred J. (B)
Borque, Robert Z. (A)
Breen, John T., Jr. (C)
Cheyney, Dan R. (B)
Davison, Quentin D. (B)
Eddings, Kenneth Earl (C)
Farkas, John, Jr. (C)
Matthews, Robert (B)
Packer, Kenneth F. (B)
Stears, Glenn B. (B)

CLEVELAND
Novy, Charles T. (D)
Richards, Gordon (A)

COLUMBUS
Edwards, Kermit James (C)

DAYTON
Gravel, Harold F. (C)
Webster, Warren E. II (C)

DETROIT
Alyea, Harold B. (B)
Belt, Richard (B)
Pozdol, Arthur M. (B)
Thomas, Donald K. (C)

FOX VALLEY
Chrusniak, Benjamin (B)
Erlandt, William K. (C)
True, Jack (B)

HOUSTON
Heney, T. R., Jr. (B)
Mayo, James A. (B)

INDIANA
Charters, Clyde C. (C)
Werner, Dave (C)

LEHIGH VALLEY
Reese, William H., Jr. (C)

LONG ISLAND
Delson, Irving (B)
McDonald, Walter (C)

LOS ANGELES
Ady, Robert George (B)
Anderson, James Y. (C)
Hookey, Paul W. (B)
Lewis, Paul H. (D)
Mallory, C. F. (C)
Metzger, Guinn E. (B)
Molander, B. L. (A)
O'Gar, Robert S. (C)
Searfoss, Lester U. (B)

MAHONING VALLEY
Daum, Warren I. (B)
Dewey, Bruce E. (B)

MARYLAND
Espy, R. Harry (C)

MICHIANA
Sherman, Henry R. (C)

MILWAUKEE
Myers, A. H. (B)
Stano, Matthew L. (C)
Treleven, Harold T. (B)

NEW HAMPSHIRE
Nadeau, Norman A. (B)

NEW JERSEY
Albom, Melvin J. (C)
Fuchs, Charles J. (C)
Sachs, David (C)

NEW ORLEANS
Alexander, William C. (B)
Kitchen, Robert L. (B)

NEW YORK
Bartholet, Emil J. (C)
Berg, Richard T. (B)
Klapper, Joseph Alan (B)
Liechti, Charles (B)
Sinclair, E. L. (A)
Whitney, Robert (C)

NIAGARA FRONTIER
Skelton, H. A. (B)

NORTHEAST TENNESSEE
Dean, Richard H. (B)
Rice, William H. (B)
Troutman, T. G. (B)

NORTHERN NEW YORK
Doherty, Charles E. (B)

NORTHWEST
Donaldson, Glenn L. (B)
Lang, M. A. (C)
Lindquist, Leroy C. (B)
Sandin, R. S. (C)

NORTHWESTERN PA.
Dunwoody, Samuel (C)
Winnen, James (D)

PEORIA
Bartel, Leonard R. (C)
Bogart, Eldred (C)
Christopher, G. Thomas (C)
McEndollar, Willard (C)
Peck, Lowell B. (C)
Philyaw, J. V. (C)
Puckett, Harold (C)
Rogers, Hershel W. (C)
Wind, Joseph B. (C)

PHILADELPHIA
Dickol, Arthur R. (B)
Goldberg, Albert L. (C)
McGinley, George S. (C)
Reeder, A. M. (C)
Reilley, James M. (B)
Rongione, Emil L. (B)
Sindora, Samuel (C)

PITTSBURGH
Doumont, C. W. (B)
Drossman, Richard O. (C)
Leighty, Roger (C)
Steinmetz, Henry O. (B)
Titera, C. George (C)

PROVIDENCE
Aronson, Albert G. (B)
Bechard, Andre P. (B)
Bianco, John A. (C)
Brunnckow, E. Everett (B)
Christensen, Axel A. (B)
Cole, James S. (C)
Corp, Clarence F. (C)
Costantino, Joseph (B)
Costantino, Ralph (B)
Crowell, Edward B. (B)
Davidson, Albert G. (B)
Diaz, Russell S. (B)
DiBenedetto, Joseph (C)
Domina, Elisha G. (B)
Downing, Clay E. (B)
Duffney, David N. (B)
Ellinwood, Walter (C)
Fenton, Barry P. (C)
Filonow, Sergi (B)
Finnerty, John (B)
Fucci, Joseph P. (C)
Greenhalgh, Arthur (B)
Hart, Russell J. (B)
Hawe, Samuel (B)
Heaton, Alfred T. (C)
Heaton, James C. (B)
Henry, Stanford H. (B)
Kelly, Francis H. (B)
Kennedy, Howard (B)
Kennedy, John (B)
Lembo, Philip (B)
Lussier, Robert E. (B)
Makepeace, William N. (C)
Mehaffey, George T. (B)
Moffitt, Harold J. (C)
Moore, Samuel (B)
Morin, Nelson H. (B)
Olson, Allen (B)
Rini, John (B)
Roppe, Joseph E. (C)
Salomon, James T. (B)
Scanlon, Robert (B)
Slater, Stanley J. (B)
Spilo, Lloyd H. (B)
Vachon, Larry (B)
Wetzel, Edmund (C)

SAGINAW VALLEY
Hadley, William B. (D)
Reese, John L. (D)

ST. LOUIS
Ellis, Orville F. (C)
Schroeder, Ira (B)
Straub, William C. (C)
Szalacha, Harry P. (B)

SALT LAKE CITY
Pater, Hendrik (B)

SAN FRANCISCO
Bartley, John E. (C)
Tellone, Elmo S. (C)

SANGAMON VALLEY
Collier, William S. (C)

SHREVEPORT
Mulhern, J. A. (B)

STARK CENTRAL
Wengerd, Alva (C)

WASHINGTON, D. C.
Goldstein, Sherwood (C)
Plane, George A. (C)
Quasebarth, William H. (B)
Vest, Charles E. (C)

WESTERN MASSACHUSETTS
Kosinski, John J. (B)

YORK-CENTRAL PA.
Bechtel, Henry Edward (C)
Ciccarelli, William E. (B)
Gessner, Carl R. (C)

MEMBERS NOT IN SECTIONS
Blanchet, Bernard (B)
Feng, Chi-Eng (C)
Folkhard, Erich (B)
Freeman, W. H. (B)
Parasuram, P. (B)
Roe, William Leslie (C)
Sims-Davies, Geoffrey (B)
Whitten, Eudell G. (B)

Members Reclassified

During the month of July

EAST TEXAS
Wallace, Larry A. (D to C)

HOUSTON
Wright, H. D. (C to B)

LOS ANGELES
Moeller, John W. (C to B)

NORTHEAST TENNESSEE
Felix, H. L. (C to B)

PEORIA
Baldwin, Harold (C to B)
Packer, Mort (C to B)

PORTLAND
Watt, Harvey M. (C to B)

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Bongio, Enrico P. (C to B)

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Current Welding Literature

For copies of articles, write directly to publications in which they appear

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STRONGER WELDS

EUTECTIC Welding News

PUBLISHED BY EUTECTIC WELDING ALLOYS CORPORATION, 40-40 172 STREET, FLUSHING 58, NEW YORK, N. Y.

MIDWEST AREA ACQUIRES EUTECTIC WAREHOUSE; Technical Information Center

A new warehouse to serve the fast growing Midwest has been opened in St. Louis by Eutectic Welding Alloys Corporation.

The warehouse will also serve as headquarters for Eutectic's Technical Information Service in the Midwest, North Central United States.

Welding users in the area are urged by Eutectic to take advantage of this new sales and service center, and avail themselves of the unique, free technical services offered by Eutectic Welding Alloys Corp.

In your own shop, factory-trained District Engineers will show you how to get every advantage of Eutectic's "Low Heat Input" metal joining methods. District Engineers (over 350 of them in the United States) have effected large savings for virtually every industry from coast to coast by suggesting welding applications which saved otherwise useless equipment, avoided lengthy downtime for repair and got rid of frequent breakdowns.

Eutectic's research labs and Technical Information Service are at your service to help you solve those "unsolvable" welding problems.

The new Eutectic warehouse will guarantee welding users in this area prompt delivery of the right rod for the job...a fresh-from-the-factory source for the more than 150 Low Temp EutecRods and Low Amp EutecTrodes manufactured by Eutectic.

Put this new Eutectic Warehouse-Service Center to work for you! To get better, faster, stronger welds and repairs call GEneva 6-4644, or write Eutectic Welding Alloys Corporation, 3719 Vest Avenue, St. Louis 7, Missouri. Do it today! ***(B-9)***

A BURNING QUESTION ONLY EUTECTIC COULD ANSWER

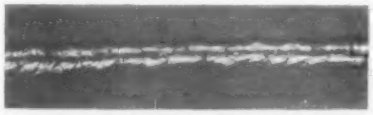
Overlays on the jaws of this "stripper" had to withstand temperatures up to 2600 F—often reached by the red-hot ingots it carries in a mid-western rolling mill. Repeated tests by the mill to find an alloys that would withstand these high temperatures resulted in failure. Conventional overlaying alloys were quickly burned off, and the frequent overlaying resulted in considerable expense, downtime and wasted labor. A Eutectic District Engineer was consulted. He recommended EutecBor #9, Eutectic's super-high alloy overlay, which has remarkable resistance to wear and corrosion at normal and elevated temperatures.

Overlays of EutecBor #9 were applied at 1800 F. Conventional overlaying materials require 2400 F. Low application temperature avoided dilution, and super-hard EutecBor #9 deposits were not mixed with softer base metal. Overlays of EutecBor #9 showed no trace of pitting or galling. In fact, as deposited it had an RC hardness of 55-62, and an RC 36-37 at 1600 F...or sufficient hardness to withstand jet aircraft exhausts.

The mill reported that EutecBor #9 overlays gave them six times greater wear than conventional overlays. ***(B-10)***

WELD FAILURES ARE COMMON WITH CONVENTIONAL HIGH HEAT WELDING ALLOYS

A conventional high heat welding alloys produced this weld. Bead was difficult to start. Deposit is porous, slag was difficult to remove. Wide amperage and voltage fluctuation occured, indicating poor weldability of electrode.



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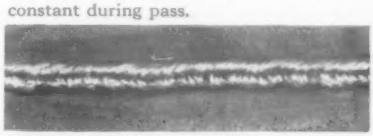

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ABSTRACTS OF CURRENT PATENTS

prepared by Vern L. Oldham

Printed Copies of patents may be obtained for 25c from the Commissioner of Patents, Washington, D. C.

2,786,434—Welders Work Holder—Orrin C. Klungtvedt, Rushford, Minn.

The patented work holder positions a pair of work clamping jaws on specialized holder means to provide controlled movement and positioning of these work clamping jaws.

2,786,933—Electric Arc Welding—Ernest Jeremy Hume, Carnegie, Victoria, Australia, assignor to Humes Limited, Melbourne, Victoria, Australia, a company of Victoria.

The patented apparatus relates to means for welding the abutted longitudinal edges of a pipe body being formed from steel plate. The plate is fashioned into an approximately cylindrical body with the two longitudinal edges in slightly spaced relationship and is passed to a welding electrode. The welding apparatus includes a small feed hopper located within the pipe body for containing and feeding flux powder to the internal welding zone in the pipe as the spaced edges thereof are welded together. Other means supply this feed hopper with flux from a storage hopper.

2,786,934—Flux Back-up Wheel for Welding—Burl B. Ohnstad, South Gate, Calif., assignor to American Pipe and Construction Co., a corporation of Delaware.

This patent relates to apparatus for use with steel sheet or the like which has adjacent edge portions to be welded together by electric arc welding means postioned above the work. The novel apparatus relates to back-up means including a wheel having the upper portion of its periphery adjacent the underside of the work. Suction means are provided for carrying flux on the upper portion of the periphery of the wheel to facilitate the desired welding action.

2,787,198—Hinged Welded Fabric—William E. White, Bethlehem, Pa., assignor to Bethlehem Steel Co., a corporation of Pennsylvania.

White's patent relates to the provision of special hinge wire means for pivotally connecting two welded rod reticular units together.

2,787,234—Holder or Setter for Welding—Joseph A. Mach, Tulsa, Okla.

Mach's patent is on a specialized apparatus for setting a nozzle or other tubular member having a flanged outer end in accurate angular relationship with a pipe for welding the inner end of the nozzle to the pipe. The setter includes a pair of spaced, upstanding shafts having ends adapted to seat on the pipe to which the nozzle is to be welded.

2,787,497—Multi-Tip Torch for Applying Hard Facing Material—Harry V. Kough, Chester, Pa., assignor to Coast Metals, Inc., Little Ferry, N. J., a corporation of Delaware.

This patent is on apparatus for applying hard surfacing material to a workpiece. The apparatus includes an oxy-fuel gas torch having a plurality of flame jet orifices spaced from each other. These flame jet orifices converge so that the projections of the orifices meet at a point beyond the intended surface of the workpiece with which the apparatus is to be used. A powder container is provided and it has a powder nozzle positioned with an outlet opening into the space between the jet orifices. Means eject powder from the container and powder nozzle at substantially lower velocity than that of the flame jets from the orifices. The apparatus is designed so that a substantial part of the powder passes through the envelope flames of the flame jets while moving to the surface of the workpiece.

2,787,698—Flash Welding Machines—Hans Alfred Schlatter and Emil Wegmann, Zollikon-Zurich, Switzerland, assignors to Firma H. A. Schlatter A. G., Zollikon-Zurich, Switzerland.

This patent relates to a flash welding machine including support for an article to be welded, and a stop member having a work engaging face and being carried by the support for movement to and from an operating position. The stop member engages a surface of the article to be welded in the operating position. A pressure member is carried by the support opposite the work engaging face of the stop member for movement towards and away from the face so that the pressure member engages an article to be welded and pressures it against the work engaging face of the stop member. A stop means is also provided and engages the stop member during its movement towards the operating position for limiting movement of the stop member and determining the operating position of the stop member.

2,787,699—Method of Butt Welding Fully Austenitic Stainless Steel Alloy Tubes—Nicholas C. Jessen, Akron, Ohio, assignor to The Babcock & Wilcox Co., New York, N. Y., a corporation of New Jersey.

This patent relates to a method of butt welding fully austenitic Cr-Ni alloy steel tubes. The method comprises the steps of building up fusion weld deposits of partially ferritic Cr-Ni alloy steel on the ends of the tubes to be welded. The ends of axially aligned tubes are then welded together with a fusion weld joint of partially ferritic Cr-Ni alloy steel and an atmosphere of inert gas, under super atmospheric pressure, is maintained inside the tubes while weld uniting the tubes together.

2,788,232—Flexible Welded Sput—Alfred C. Stadthaus, Mayville, Wis., assignor to Mayville Metal Products Co., Mayville, Wis., a corporation of Wisconsin.

This patent covers a special metal container having a sput welded thereto to give some flexibility therebetween.

2,788,233—Arc Brazing and Pins Therefor—Maurice A. Enright, Lorain, Ohio, assignor to Gregory Industries Inc., Detroit, Mich., a corporation of Michigan.

Enright's invention relates to a novel brazing pin and to a method of brazing it to a workpiece. The brazing method includes the steps of melting the brazing material and cleaning opposing surfaces on the pin and work by establishing an arc between the brazing material and the work, and then the pin is moved towards the work and some of the brazing material is allowed to solidify on the pin and work to form a brazed joint.

2,788,429—Process and Gas for Inert Gas Shielded Arc Welding—Eugene L. Turner, Kansas City, Mo., and Earl W. Seufert, Kansas City, Kans., assignors to General Motors Corp., Detroit, Mich., a corporation of Delaware.

This patent relates to an arc welding process wherein the novelty relates to shielding the arc with a blanket of gas consisting of a uniform mixture of one part by volume nitrogen and from about 20 to 22 parts by volume helium.

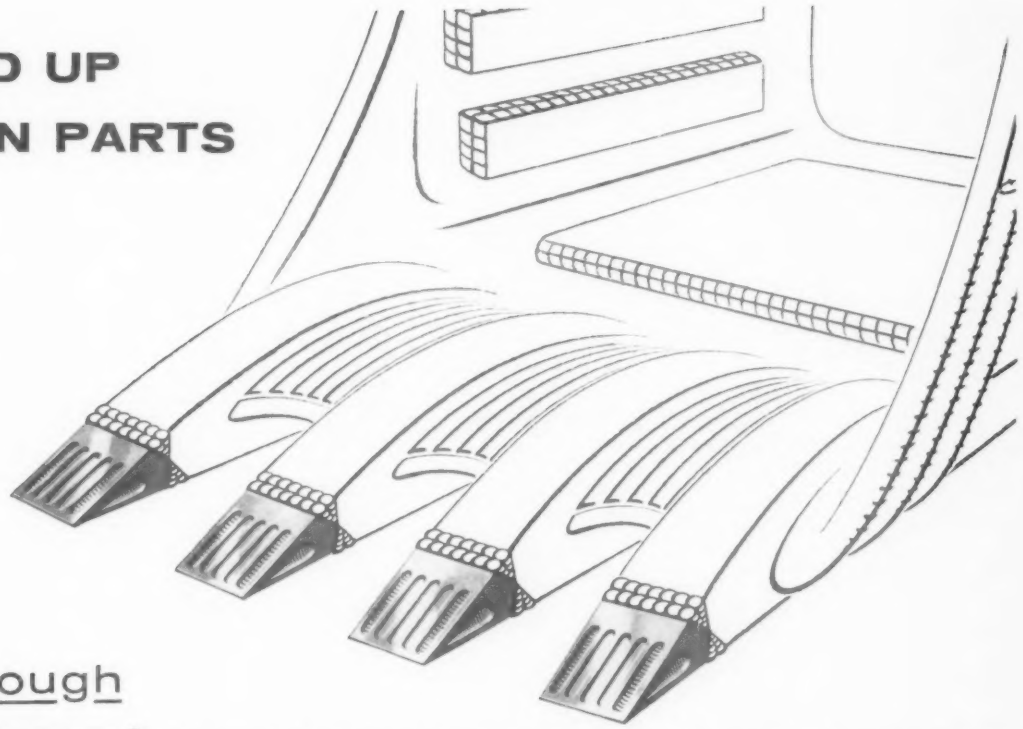
2,788,430—Gas Saving Weld Box—Sterling A. Oakley, Lincolnwood, Ill.

The patented welding box is adapted for compressing and positioning a continuous article to be welded as it passes through a chamber provided by the weld box. Other means maintain a suitable atmosphere in the chamber defined by the box.

2,788,431—Welding Apparatus for Semiconductor Translating Device—Fred Wohlman, Jr., Inglewood, Calif., assignor to Hughes Aircraft Co., Culver City, Calif., a corporation of Delaware.

A specialized welding apparatus of the type indicated is disclosed in the patent. The apparatus includes a member for positioning a quantity of mercury and one element is disposed in the mercury to effect electrical contact between such element and the source of electrical energy. Other means are provided for moving and supporting a second element and to apply a welding pulse so as to secure the two elements together.

BUILD UP WORN PARTS



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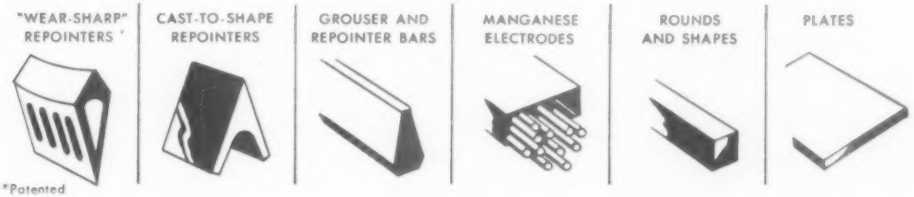

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NEWS of The Industry

Course In Metallurgy

The Milwaukee School of Engineering is adding a new course in metallurgy technology to its curriculum offerings starting with the Fall Quarter in September, 1957.

The course will be an 18-month technical institute type curriculum leading to an Associate in Applied Science degree in Metallurgy Technology.

Included in the metallurgy curriculum, in addition to mechanical technology subjects, will be Elementary Physical Metallurgy, Advanced Foundry, Ferrous Metallurgy, Nonferrous Metallurgy, Metal Surfacing, Metallurgical Design, and Welding Metallurgy.

Airco Breaks Ground for $9,000,000 Plant

The Air Reduction Sales Company division of Air Reduction Co., Inc., today started construction of its multimillion dollar air separation plant in Acton, Mass., near Boston. The cost of the plant including related distribution facilities, will be in excess of $9,000,000. The new Air Reduction facility, which is scheduled for completion during the Summer of 1958, is designed to produce 75 tons of liquid oxygen, nitrogen, and argon per day.

When completed, the Acton plant will be the fifth large air liquefaction plant to be constructed by Air Reduction. The company already operates such plants at Butler, Pa., Riverton, N. J., and Chicago, Ill., and will soon complete construction of a plant at Los Angeles, Calif.

G. E. Electronic Expands

The Electronic Tube Division of the General Electric Co. moved its sales offices in August from Schenectady, N. Y., to Owensboro, Ky., which now is headquarters for the entire electronic components division. According to John T. Thompson, manager of distributor sales of G. E. electronic components, the change is designed to broaden the scope of the company's nation-wide distributor sales organization.

The field sales force consisting of a network of 32 district sales managers and five regional sales managers will continue in their present office locations in 27 cities throughout the country. Additional offices will be established when customer service requires as the parts distribution industry expands.

Resistance Welding Shipments Steady

Statistics compiled by the Resistance Welder Manufacturers' Association indicate that shipments of resistance welding equipment by members during the first six months of 1957 have maintained an active pace, and are only slightly below shipments for the same period of 1956.

June shipments were more than $\$2^1/_2$ million, the fourth consecutive month above that figure.

Backlog at the end of June was reported at nearly $11 million.

TANK CONSTRUCTION

Shop fitting is an important step in tank construction. This operation is seen being performed on a big acid tank by workmen at McAleenan Brothers Co., Pittsburgh, Pa., a subsidiary of Overly Manufacturing Co. This 21,330 gallon tank is made of 3/8-in. steel plate and measures 18 ft in diam by 14 ft in height. It will be bonded with lead and lined with acid brick and will be used by the Titanium Division of the National Lead Co. to store sulphuric acid at a temperature of 230 deg F. The tank was shop fitted to assure accuracy before being dismantled for shipment.

Institute of Welding Elects

Sir Charles Lillicrap and John Strong have been re-elected for a second year as president and vice-president, respectively, of the Institute of Welding.

Sir Charles Lillicrap is a former Director of Naval Construction of the Admiralty. Mr. Strong is the Chairman of Quasi-Arc Limited.

Course In Safety

The Institute of Welding is organizing a special one-day course for nurses in industry and safety officers to be held in London in the autumn.

The course aims to explain how the welding processes give rise to certain hazards, and to describe their clinical effects; the law in regard to the use of welding, and the steps necessary to ensure the health and safety of the people who work with the processes, will be discussed.

COMING EVENTS

A Calendar of Welding Activity

AWS National Meetings

1958 Spring Meeting and Welding Show:
April 14–18, Statler Hotel, St. Louis, Mo.

NWSA

West Central Zone Meeting:
November 11–12, 1957, The Cosmopolitan, Denver, Col.

Western Zone Meeting:
November 14–15, 1957, Riviera Hotel, Las Vegas, Nevada

ASM

November 4–8, 1957. Thirty-ninth National Metal Exposition & Congress, concurrently with Second World Metallurgical Congress, International Amphitheatre, Chicago, Ill.

Tube Turns Observes 30th Anniversary

Tube Turns, Louisville, Ky., observed its 30th anniversary on July 19.

The company, a division of National Cylinder Gas Co., Chicago, is the nation's largest manufacturer of welding fittings and flanges for industrial piping systems, and a major producer of forgings for jet and conventional aircraft engines.

Tube Turns was founded by M. Keith Dunham, who served as president until 1939; Walter H. Girdler, Sr., who headed the company until his death in 1945; Charles J. Haines, now president of National Cylinder Gas Co., the parent organization, and E. G. Luening.

George O. Boomer, chairman of the executive committee of the National Cylinder Gas Co., was president of Tube Turns from 1945 until his retirement in 1956. He was succeeded by John G. Seiler.

When Tube Turns began business three decades ago, it was the first producer of forged seamless welding fittings in the United States. As the company grew, branch plants were established at Los Angeles in 1950, and at Houston in 1953. In 1948, Tube Turns of Canada Ltd., a subsidiary of National Cylinder Gas Co., was organized to serve the Canadian market, and it has a modern plant at Ridgetown, Ontario.

Tube Turns was owned equally by the Keith Dunham Co. and the Kentucky Oxygen Hydrogen Co., and their successors, the National Cylinder Gas Co. and The Girdler Corp. until June 1, 1953. On that date the National Cylinder Gas Co. and The Girdler Corp. merged, and Tube Turns became a subsidiary of National Cylinder Gas Co. It became a division on Jan. 1, 1954.

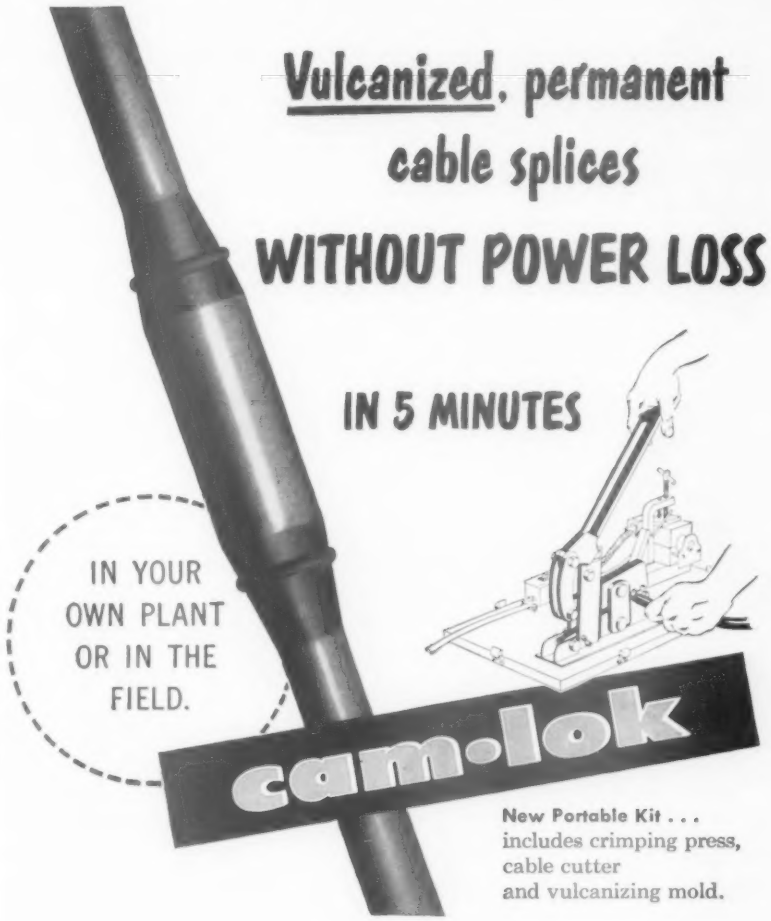
The products of Tube Turns are used chiefly by the petroleum, gas transmission, power, chemical, nuclear energy, aircraft and other industries that are rapidly expanding.

Air Products Purchases Aldan Oxygen

Air Products, Inc., Allentown, Pa., has acquired the assets of Aldan Oxygen Manufacturing Co., Philadelphia, it was announced by Leonard P. Pool, president of Air Products.

According to Mr. Pool, the acquisition will permit Air Products to extend its Cylinder Gas Division activities into Philadelphia and surrounding area. The Philadelphia operation will operate as Air Products, Incorporated under the management of E. J. Rosser, who founded the Aldan Co. in 1942.

Aldan Oxygen Manufacturing Co. manufactures and distributes oxygen,



New CAM-LOK portable Cable Splicing Kit produces vulcanized, neoprene insulated cable splices anywhere in just 5 minutes . . . makes them waterproof, shockproof.

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NCG Licensed to Make Swiss Rail Welders

Exclusive U. S. manufacturing rights to a Swiss machine that can weld standard railroad rails into one continuous quarter mile length in less than two and one-quarter hours have been obtained by National Cylinder Gas Co., it was announced by Charles J. Haines, president.

The arrangement also covers manufacturing rights in Canada, Mexico, Central America and most of South America.

License agreements to make the patented automatic rail welder have been signed with H. A. Schlatter AG., world-famous Swiss manufacturer of resistance welding machines, Mr. Haines said. Work is under way to establish production of the entire unit in this country.

Continuous-welded rails, Mr. Haines said, provide a smoother ride, eliminate the "clickety-clack" of cars over rail gaps, reduce maintenance on cars damaged by running over uneven rail joints and virtually eliminate wear on rail ends and the high cost of track maintenance caused by low joints.

The Schlatter rail flash resistance butt welder, NCG spokesmen said, can perform at a rate of 15 rail joint welds per hour—two to three times faster than conventional rail welding methods. Costs are estimated to be as low as half those for conventional unwelded joints or other welding methods used in this country.

The entire unit—welder, diesel electric power unit and auxiliaries—occupies three full-size railway freight cars.

Tepley and McFadden Form Company

Organization of the Industrial and Utilities Specialty Co. to furnish southeastern industries a specialized consulting service on materials, tools, and equipment has been announced by E. J. McFadden and George L. Tepley. The firm's headquarters will be in Chattanooga, Tenn. and they will specialize in the metallurgical, ceramic, and welding fields.

McFadden has been General Manager of Combustion Engineering Inc.'s Home Equipment Division for eight and one-half years and previously spent ten years with the General Electric Co. Tepley comes from the C. D. Genter Co. and the Chattanooga Welders Supply Co., specializing in the metallurgical, welding, and alloy fields.

Mr. Tepley is a member of the American Welding Society.

Aeroprojects Forms Subsidiary

Aeroprojects Inc. of West Chester, Pa., has recently formed a subsidiary company, Sonobond Corp., to manufacture, sell, and service ultrasonic metal joining equipment that Aeroprojects has developed. Formation of the new company was announced by Aeroprojects' president, J. Byron Jones.

Aeroprojects' management has long recognized that manufacturing, sales engineering, selling, and servicing of ultrasonic equipment should be divorced from Aeroprojects' normal activity, which is essentially research and development of ultrasonic applications at the power level. Accordingly, Sonobond Corp. has been organized to devote its effort to assisting industry in the use of the three novel lines of ultrasonic metal joining equipment developed by Aeroprojects during the past six years: Sonoweld, ultrasonic non-fusion welding equipment; Sonobraze, ultrasonic fluxless brazing equipment; and Sonosolder, ultrasonic fluxless soldering equipment. This is the only company in the world known to specialize in the manufacture, sales, and service of an extensive line of ultrasonic metal joining equipment.

Aeroprojects vice-president W. C. Potthoff has been named president of Sonobond Corp. which will also be located in West Chester, Pa.

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PHOS-SILVER* #2—Low cost, but less fluid than PHOS-COPPER—to bridge gaps, and fill "open" joining. Brazing range: 1325° to 1375°. *T.M.

PHOS-SILVER—For critical, tightest joints. *Extremely* penetrating! *Excellent* for brass and bronze. Brazing range: 1225° to 1275°.

PHOS-SILVER 6M — Mushy, easily controlled flow. Off-sets poor fit-up. Bridges 1/8" gaps. Especially ductile! Brazing range: 1275° to 1350°.

PHOS-SILVER 15 — Mushy flow characteristics. Wide melting range. Available for government specifications. Brazing range: 1325° to 1375°.

Convenient packaging, 18" lengths, 1-lb and 5-lb tubes. Standard 25-lb package, 36" lengths. SAME ALLOYS AVAILABLE IN ROD FORM—WIRE IN COILS—or in rings!

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For more details, circle No. 28 on Reader Information Card

Correspondence Course in Resistance Welding

The Resistance Welder Manufacturers' Association in conjunction with the International Correspondence Schools have completed final preparation for an I.C.S. course in resistance welding technology.

Students in this course will acquire the knowledge of the operation of all types of resistance machines. They will learn various welding techniques and their applications in each specific type of welding, and the methods and proper procedures necessary for quality welding operations.

For more complete details, write to the Resistance Welder Manufacturers' Assn., 1900 Arch St., Philadelphia 3, Pa

Annual Meeting for Independent Welding Distributors

The Independent Welding Distributors Association held their ninth annual meeting in Reno, Nevada on June 27–28, 1957.

Distributor members and their families from Alaska, Hawaii, and the Western United States attended this two day meeting.

The election of officers for the year 1957–58 named Otto Koll, Welders Supply Service, Modesto, Calif. as president and W. V. Raymond AWS, California Welding Supply Co., Stockton, Calif., vice-president. M. J. Andrews, Salinas, Calif., was retained as secretary-treasurer.

The Directors are: S. J. Sigler, Sigler's, Fresno, Calif., M. F. Coyne, California Oxygen Co., Sacramento, Calif., T. M. Kean, Sierra Oxygen Co., Reno, Nevada, H. E. Bailey AWS, Bailey Equipment Co., San Diego, Calif., O. H. Koll, Welders Supply Service, Modesto, Calif., R. F. Balaam AWS, Balaam Brothers, Emeryville, Calif., and W. V. Raymond, California Welding Supply Co., Stockton, Calif.

The next annual meeting of the Independent Welding Distributors Association will be held at Disneyland in Anaheim, Calif.

K-G Appoints Distributor

The California Oxygen Company of Los Angeles has been named to handle K-G Equipment Co. welding and cutting equipment in California, through its eight outlets in that state.

Karl Schmuldt, vice-president of The K-G Equipment Co. of Allentown, Pa., pointed out that complete inventory and service facilities will now be available for customers at San Diego, Los Angeles, Salinas, Watsonville, San Francisco, Sacramento, Yuba City and Redding.

Crimping-roll life increased 1,000%

High-carbon steel rolls overlaid with AMPCO TRODE® 300 Aluminum-Bronze Electrode

In forming irrigation couplers and sprinkler outlets, crimping rolls had to be replaced every 7,000 pieces. Metal-to-metal wear was severe.

But then, mandrel and wheel were overlaid with Ampco-Trode 300. 70,000 pieces had been produced at the time the picture above was taken, and the male and female rolls were still going strong.

Scrap losses were practically eliminated. So were scratching and galling — reworking costs went down substantially.

Can you enjoy similar savings on *your* drawing and forming operations? Talk it over with your nearby Ampco distributor. Or mail coupon below today.

Sole producer of genuine Ampco Metal

AMPCO®

AMPCO METAL, INC.,
Milwaukee 46, Wisconsin
West Coast Plant: BURBANK, CALIFORNIA

®Reg. U. S. Pat. Off.

Tear out coupon and mail today! W-145

AMPCO METAL, INC.
Dept. WJ-9, Milwaukee 46, Wis.

Send me your latest bulletin giving further information on Ampco-Trode 300 and other Ampco electrodes.

Name_____

Company_____

Address_____

City_____ Zone____ State_____

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Diamonite Appoints Distributors

Diamonite Products Manufacturing Co., Canton 3, Ohio, has named Welding Process Equipment Corp., 1302 Bryn Mawr Ave., Chciago 40, Ill., to handle sale of Diamonite shielded-arc welding cups in the Chicago trading area, including portions of Iowa and Indiana, as well as Illinois. President and general manager of the newly-appointed firm is William P. Good.

The second distributor appointed by Diamonite Products is Ford Supply Co., 3120 Mapee Drive, N. E., Atlanta 5, Ga. Ford will distribute for Diamonite from its Atlanta warehouse in the states of Florida, Georgia, North and South Carolina, Alabama, eastern Tennessee and the District of Columbia. Frank Ford, is president of the firm, which was formerly Frank Ford and Associates, manufacturers agents.

Both Mr. Good and Mr. Ford are members of the AMERICAN WELDING SOCIETY.

Transfers at M & T

Metal & Thermit Corp., New York, has announced the following transfers, effective July 1st, among members of its middle management group:

D. W. Oakley, previously technical advisor to the president has been made production manager. Mr. Oakley has been with Metal & Thermit since 1947 and from 1952 to 1956 was manager of its Carteret, N. J., plant.

H. A. Rack, who was production manager, has been appointed manager of engineering. Mr. Rack has been with the company in various engineering and managerial capacities since 1944.

C. H. Carpenter, Jr., has been appointed technical advisor to the president. Mr. Carpenter joined Metal & Thermit in 1955 as assistant manager of market development.

K. E. Doud, has been made assistant manager of engineering.

R. E. Davis has been transferred from the company's central engineering department to its market development division.

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Offers You Over 200 PROVEN Standard Stock Models of Quality POSITIONERS "POSITIONEERED" to your exact Requirements
Patented
Aronson TracTred (T. M. Reg.) Turning Rolls for thin-walled heavy cylindrical work to 27 tons capacity. Zero to 100 IPM turning speed and Built-In Grounding.
Heavy Duty Precision Built Rubber and Steel Tired Turning and Pipe Rolls, 100% overload protected. Capacities to 300 Tons.
Heavy Duty Gear Driven Positioners, with Magnetic Braking, Mercury Grounding, and Optional Speeds. Capacities to 120,000 lbs.
Fully Automatic Gear Driven Positioners, featuring Power Elevation, Tilting and Rotation. Capacities to 120,000 lbs.
Heavy Duty Floor Turntables with precision speed control and Magnetic Braking, used for welding, burning, X-raying, etc. Capacities to 120,000 lbs., various heights and speeds.
Model D Gear Driven Positioners. Compact, Precise, Rugged. Capacities to 1000 lbs.
Bench Turntable Automatic Positioners with Mercury Grounding Capacities to 500 lbs.
Patented
Aronson-Twinner Permanent Magnetic Clamps, six models with thousands of uses in welding set-up work. Write for bulletin.
Aronson Universal Balance Positioners (T. M. Reg.) position your weldments effectively, instantly for downhand welding. Capacities to 2000 lbs.
Rugged Head and Tail Stock for positioning bulky weldments between centers. Table Backup for Zero Deflection, Magnetic Braking. Capacities to 160,000 lbs.
Write for detailed engineering data
Quality POSITIONERS by Aronson MACHINE COMPANY
ARCADE, NEW YORK
For more details, circle No. 30 on Reader Information Card

Sales Districts Increased by A. O. Smith

To provide better customer service, the A. O. Smith Corp's. Welding Products Division has increased the number of its sales districts, according to R. W. Raney, division general sales manager.

L. G. Crowley continues to manage the Milwaukee area sales force. Sales personnel in the newly created Chicago and Detroit districts now report to W. P. Finneran and A. M. Brinson, former sales representatives in those cities.

D. H. Buerkel will continue direction of the Atlantic States sales force. Supervision of remaining districts is unchanged.

The Messrs. Raney, Crowley, and Buerkel are members of the AMERICAN WELDING SOCIETY.

Helium Aids Satellite

Helium, an "inert" gas, will help boost the first man-made earth satellite Vanguard beyond the pull of gravity and into its world-encircling orbit.

Helium is being supplied under government contract through National Cylinder Gas Co. to Aerojet-General Corp., Los Angeles, builder of the second-stage propulsion system for the Vanguard vehicle.

The rare gas, which takes its name from the Greek word for sun, helios, will be used in pressurizing the liquid-propellant tanks for the second-stage rocket engine of the satellite's launching vehicle.

The second-stage propulsion system being constructed by Aerojet takes over at about 37 miles and is expected to boost the unit containing the satellite up to about 300 miles. There the third stage will be ignited and accelerate the satellite to the necessary speed to maintain an orbit.

Prime contractor for the Vanguard satellite is The Martin Co.

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THERMO *Spiral*

TIP CLEANER

The exclusive, non-breakable advantage of THERMO TIP cleaners didn't just happen—No Sir! This feature resulted after 10 years research, and experience. That's why we say no other type or make can match a THERMO; and the best way to prove that statement is to send for a FREE THERMO Spiral Tip Cleaner and put it to every test—as to its cleaning efficiency and long lasting performances. Yes, just TRY to break it—then you'll know why—

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Eutectic Expands Abroad

"By 1958, overseas production capabilities of Eutectic 'Low Temperature Welding Alloys' will be strongly augmented by establishment of new plants in Brazil and Switzerland," it was announced by Rene D. Wasserman, President, Eutectic Welding Alloys Corp., 40-40 172nd St., Flushing 58, N. Y.

This announcement of "Eutectic's" expansion plans followed dedication ceremonies for a new plant which began operations in London, England, in February.

To meet the needs of expanding South American industry, a newly acquired plant in Sao Paulo, Brazil is now being equipped. Initial production is scheduled for June.

Simultaneously, final architectural plans and specifications for a new plant in Lausanne, Switzerland, have also been prepared and approved. Actual construction is now in its initial stages, with completion scheduled for early 1958.

"An international network of regional plants sensitive to local industrial requirements is our objective," Mr. Wasserman said. "As an industrial market develops we will be sufficiently manned and equipped to provide needed welding alloys to effect maximum weld savings."

Executive Changes at Marion

James Mullaney, president of Universal Marion Corporation has announced the promotion of Adrien F. Busick, Jr., vice-president, engineering, to the position of executive vice-president and general manager of Marion Power Shovel Co. Mr. Busick will have complete charge of all functions and operations of the plants at Marion. This appointment will permit Milton T. Smith, president of the division, to devote his time to furtherance of customer relations and promotion of the company's products, Mr. Mullaney stated.

A further announcement was made of the voluntary retirement of David E. Rizor, vice-president, Large Machine Sales. He was succeeded by Maurice V. Cornell who assumed that position effective Aug. 1, 1957.

Election of William R. LeMasters to the additional position of vice-president was also made known. Mr. LeMasters was recently elevated to the position of secretary-treasurer.

Mr. Busick joined Marion in 1929 and has continuously served in engineering and corporate staff functions. He is a member of the AMERICAN WELDING SOCIETY.

Mr. Rizor has enjoyed continuous service with Marion since 1928 in the sales department and as an officer of the company. Mr. Cornell was formerly associated with Marion Power Shovel Co. in sales.

Man, this ZIP electrode's the greatest!

He's right. The new Westinghouse ZIP-14 universal electrode handles easily in all positions, has very low spatter loss, deep penetration, fast burnoff, feather-touch slag removal and a quiet, smooth arc. This powdered-iron electrode fits both E-6014 and E-7014 classifications. There's no burning through, no undercutting even on vertical down work.

What more can you ask for in an electrode?

We know you'll like it. Try it in your own shop—under your conditions! It will sell itself! J-21984

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For more details, circle No. 31 on Reader Information Card

Aluminum cranes are now being welded using semiautomatic equipment.

New Alcoa welding alloy makes possible the aluminum crane

For a long time, the idea of an aluminum crane has interested designers. Much lighter in weight, it would permit lower cost building foundations or a higher capacity crane on the same foundations. But how to make it? Riveted construction is outmoded and expensive.

Now aluminum cranes are being built, thanks to a new Alcoa alloy. Designated 5456, this new alloy has the highest as-welded strength of any commercial aluminum alloy yet developed. Guaranteed minimum properties are 42,000 psi ultimate and 19,000 psi yield on the plate and equally good ultimate strength across the weld.

Using the new alloy and the inert-gas consumable-electrode process, it costs no more to fabricate aluminum cranes than steel cranes. There are long welding runs involved, up to 60 feet, and semiautomatic equipment is used. Speeds as high as 80″ per minute are achieved.

In addition to their light weight, these aluminum cranes can be used in corrosive atmospheres and will require no painting.

Alcoa is headquarters for fresh and exciting ideas like this on how to weld, braze or solder aluminum. Get in touch with an Alcoa distributor listed at right. And write now for booklets and films that show how easy it is to weld, braze and solder aluminum. Aluminum Company of America, 1741-J Alcoa Building, Pittsburgh 19, Pa.

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ALCOA ALUMINUM
WELDING PRODUCTS
ALUMINUM COMPANY OF AMERICA

Your Guide to the Best in Aluminum Value

For more details, circle No. 33 on Reader Information Card

Want technical help in welding, brazing or soldering aluminum? Contact your Alcoa sales office, listed under "Aluminum" in the Yellow Pages of your phone book.

For immediate delivery of Alcoa welding products, call your Alcoa outlet listed below. He carries a complete range of alloys and sizes.

ALABAMA
Birmingham
Hinkle Supply Co.
CALIFORNIA
Los Angeles
Ducommun Metals & Supply Co.
Pacific Metals Company, Ltd.
San Francisco
Pacific Metals Company, Ltd.
COLORADO
Denver
Metal Goods Corp.
FLORIDA
Jacksonville
J. M. Tull Metal & Supply Co., Inc.
Miami
J. M. Tull Metal & Supply Co., Inc.
Tampa
J. M. Tull Metal & Supply Co., Inc.
GEORGIA
Atlanta
J. M. Tull Metal & Supply Co., Inc.
Southern Oxygen Co.
ILLINOIS
Chicago
Machinery & Welder Corp.
Steel Sales Corp.
Moline
Machinery & Welder Corp.
KENTUCKY
Louisville
Williams and Co., Inc.
LOUISIANA
New Orleans
Metal Goods Corp.
MARYLAND
Baltimore
Southern Oxygen Co.
Whitehead Metal Products Co., Inc.
Bladensburg
Southern Oxygen Co.
Salisbury
Southern Oxygen Co.
MASSACHUSETTS
Cambridge
Whitehead Metal Products Co., Inc.
MICHIGAN
Detroit
Steel Sales Corp.
MISSOURI
Kansas City
Metal Goods Corp.
St. Louis
Metal Goods Corp.
NEW HAMPSHIRE
Nashua
Edgcomb Steel of New England, Inc.
NEW JERSEY
Harrison
Whitehead Metal Products Co., Inc.
Merchantville
Southern Oxygen Co.
Vineland
Southern Oxygen Co.
NEW YORK
Albany
Whitehead Metal Products Co., Inc.
Buffalo
Whitehead Metal Products Co., Inc.
New York
Southern Oxygen Co.
Whitehead Metal Products Co., Inc.
Syracuse
Brace-Mueller-Huntley, Inc.
Whitehead Metal Products Co., Inc.
NORTH CAROLINA
Asheville
Southern Oxygen Co.
Charlotte
Southern Oxygen Co.
Greensboro
Southern Oxygen Co.
Raleigh
Southern Oxygen Co.
OHIO
Cincinnati
Williams and Co., Inc.
Cleveland
Nottingham Steel & Aluminum Co.
Williams and Co., Inc.
Columbus
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Toledo
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OKLAHOMA
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TENNESSEE
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Knoxville
Southern Oxygen Co.
TEXAS
Dallas
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Houston
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UTAH
Salt Lake City
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VIRGINIA
Arlington
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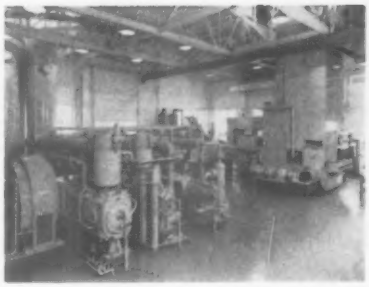
Lynchburg
Southern Oxygen Co.
Norfolk
Southern Oxygen Co.
Richmond
Southern Oxygen Co.
Roanoke
Southern Oxygen Co.
WASHINGTON
Seattle
Pacific Metal Co.
WEST VIRGINIA
Bluefield
Southern Oxygen Co.
WISCONSIN
Milwaukee
Machinery & Welder Corp.



Gas Produced for Northwest

The first liquid oxygen, nitrogen and argon producing plant in the Pacific Northwest is now in production at Industrial Air Products Co., according to Gilbert Schnitzer, president.

The 25-ton capacity plant has been under construction for the past 18 months and its completion assures Northwest industry, hospitals and government agencies of a continuing supply of liquid gases. This latest installation has increased Industrial Air's oxygen producing plant area to some 20,000 sq ft.

Supplementing the new plant, four liquid oxygen trailers have been added by Industrial Air to provide delivery of large quantities of these gases at one time for customer storage and use.

PLAN NOW
for
1958 AWS NATIONAL SPRING MEETING
APRIL 14–18
ST. LOUIS, MO.

WELDESIGN SEMINAR SPONSORED BY LINCOLN

Machine designers from a variety of companies and different sections of the country discuss their problems in search of better ways to design machinery weldments. This interest in welded machine design was revealed at the first of a series of machine design seminars being offered this year by The Lincoln Electric Co. at their Cleveland, Ohio, plant. The seminar lectures and discussions cover both design and welding and how to relate the two for the best designs. Participants also present their own problems for discussion by the group. Lincoln has scheduled additional seminars to be held in Cleveland, which are open to designers and engineers interested in the redesign of castings and the design of weldments.

INTERNATIONAL WELDING NEWS

10th Annual Meeting Held By IIW In Essen

The 1957 Annual Assembly of the International Institute of Welding was organized by the Deutscher Verband Für Schweisstechnik (German Welding Society) and was attended by nearly 800 delegates and their wives from 21 countries. It was held in Essen from June 30th to July 6th; the first 3 days coincided with the DVS Exhibition "Welding and Cutting" which many participants visited.

The program for the Assembly, which was excellently organized by a German Organizing Committee, included two meetings of the Governing Council of the Institute, four meetings of each of its fifteen technical Commissions and a public session of the presentation of papers. In addition, opportunities were given for delegates to meet socially, and a full program of entertainment was organized for ladies accompanying them.

The outgoing president, Dr. Howard Biers [illegible], was unfortunately prevented by illness from attending the Assembly, throughout which the president's duties were performed by the deputy president, Professor H. E. Jaeger (Netherlands). Dr. U. Guerrera (Italy), who was elected in 1956 to succeed Dr. Biers, was installed as the new president at the end of the Assembly.

Professor F. Rapatz (Austria) and Professor M. Radojkovic (Yugoslavia) were elected vice-presidents of the Institute in succession to Dr. C. G. Keel (Switzerland) and Señor Vilanova (Spain).

The treasurer, W. Edstro (Sweden) and the Secretary-General, G. Parsloe (United Kingdom) were each re-elected for further terms of office of 3 years.

The Slovenian Institute of Welding of Ljubljana (Yugoslavia) and the Centre for Technical Research of Timisoara (Rumania) were elected members of the Institute. The latter is the first Rumanian body to join, and its election brings the number of countries represented on the Institute up to 25.

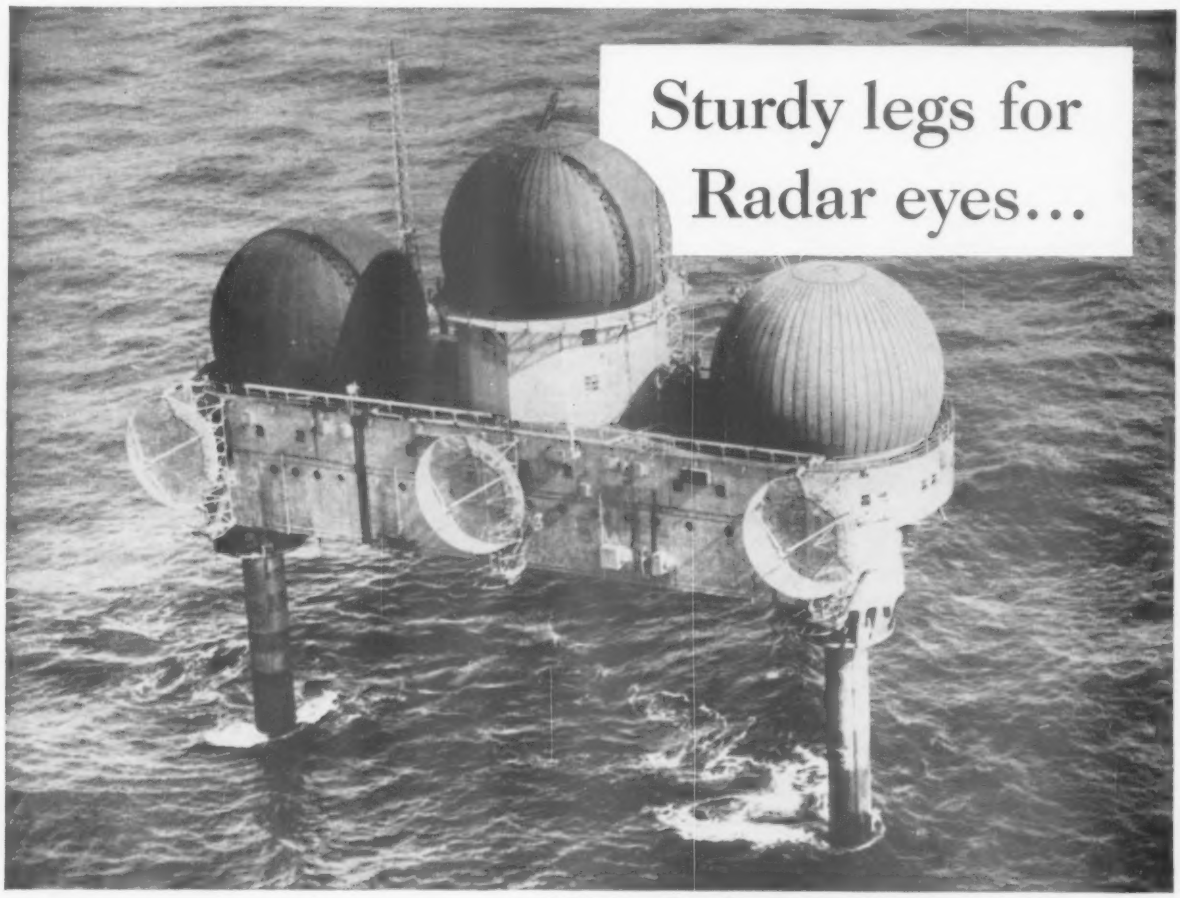
The American delegation, 29 strong, was headed by William Spraragen, sponsor delegate to the IIW and director of the Welding Research Council. Others in attendance were A. Amirikian, Bureau of Yards and Docks, Dept. of the Navy; E. J. Brady, president of Alloy Rods Co.; David P. Brown, president of the American Bureau of Shipping; Arthur R. Gatewood, vice-president—engineering of the American Bureau of Shipping; F. X. Gilg, executive assistant of Babcock & Wilcox Co.; T. J. Griffin, Bureau of Ships of the Dept. of Navy; Wm. J. Harris, Jr., assistant to director of Battelle Memorial Institute; Frank W. Hussey, chief of the metal joining branch of Pitman-Dunn Labs., Frankford Arsenal; T. Embury Jones, president of Precision Welder and Flexopress Corp.; A. N. Kugler, chief welding engineer, Air Reduction Sales Co.; L. J. Larson, construction engineer—welding, Allis-Chalmers Mfg. Co.; Niels C. Miller, president of Miller Electric Mfg. Co.; Ernest F. Nippes, Dept. of Metallurgical Engineering, Rensselaer Polytechnic Institute; Fred G. Outcalt, asst. mgr., electric welding, Linde Co.; George Pease, Welding Section, Res. Lab., International Nickel Co.; Raymond A. Pulk, Detroit Arsenal; Marvin G. Sedam, Alloy Rods Co.; Solomon Sheer, Department of Buildings, City of New York; D. C. Smith, chief metallurgist, Electrode Division, Harnischfeger Corp.; Robert D. Stout, head of the Department of Metallurgical Engineering, Lehigh University; Helmut Thielsch, metallurgical engineer, Grinnell Co. Inc.; Bruno Thürliman, Fritz Engineering Lab., Lehigh University; R. W. Vanderbeck, chief res. engr., structural and plate, applied res. lab., U. S. Steel Corp.; J. S. Vanick, development and research div., International Nickel Co.; Rene D. Wasserman, president of Eutectic Welding Alloys Corp.; T. T. Watson, Lukens Steel Co.; C. W. Wheatley, A. O. Smith Corp.; and Z. J. Fabrykowski, Research and Development Div., Ordnance Tank-Automotive Command.

Part of the audience attending the Tenth Annual Meeting of the IIW Public Session, Essen, Germany, on Monday, July 1, 1957

Work of the Commissions

Useful work was accomplished by the Commissions of the Institute at the Essen meetings and will be described in reports by their Chairmen which will be issued later in the year.

Many of the decisions taken and later ratified by the Governing Council concerned the release, for publication in the technical press, of documents prepared either by the Commissions or by individual members of them. These documents, which number 22, concern: filler metals for surfacing; the hydrogen content in weld metal; the testing and inspection of spot welds; recommended practices for flash welding with preheating; recommended practices for radiographic inspection of fusion-welded joints on steel plates up to 2 in. (50 mm) thick; a reference block for ultrasonic inspection; magnetic-particle methods of inspecting welds; standardization (arc welding equipment, resistance welding equipment and filler metals and electrodes); an acceptance method of testing weldable steels using the V-notch Charpy test; the slow notch-bend test; welding cracks in the heat-affected zone of air hardenable alloy steel; brittle fracture; the stress relief of alloy steels; fatigue (examples of fatigue failure, statistical interpretation of fatigue test results); the training of welding instruc-



One of America's offshore radar warning towers—Texas Tower III—built by Walsh Holyoke Division, Continental Copper and Steel Industries, Inc.

...with each seam checked on Kodak Industrial X-ray Film, Type AA

2700 tons of island rest on these 272-foot welded caissons. With giant seas and howling gales to stand against, every seam must be sound. Radiography provided the evidence of each weld's quality.

Each weld was radiographed using a 10 curie pill of cobalt 60. And because Kodak Industrial X-ray Film, Type AA, provides greatly increased film speed, exposure times could be moderate.

While giving speeds up to twice that of the former Kodak Type A Film, this new film retains the fine sensitivity characteristics which made Type A the most widely used x-ray film in industry.

Your x-ray dealer and the Kodak Technical Representative will gladly tell you how this new film can improve your radiographic operation and help you get more out of your present x-ray or gamma-ray equipment. It can pay you to get in touch with them.

Read what the new Kodak Industrial X-ray Film, Type AA, does for you:

- Reduces exposure time—speeds up routine examinations.
- Provides increased radiographic sensitivity through higher densities with established exposure and processing technics.
- Gives greater subject contrast, more detail and easier readability when established exposure times are used with reduced kilovoltage.
- Shortens processing cycle with existing exposure technics.
- Reduces the possibility of pressure desensitization under the usual shop conditions of use.

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tors; and edge preparation for fusion welding.

The Governing Council also considered the special arrangements to be made for the publication of a document on the influence of various factors in the radiographic examination of butt welds and on the comparison of different types of imago-quality indicators.

In addition, the Governing Council approved the publication, under the auspices of the IIW, of: a revised edition of the *Classification Table* for the Institute's quarterly *Bibliographical Bulletin for Welding and Allied Processes:* a handbook on radiographic apparatus and technique; and the "Arc Welding" section of the Institute's *Multilingual Collection of Terms for Welding and Allied Processes.*

A certain number of documents was also approved for forwarding to the International Standards Organization (ISO) with which the Institute continues to work in close collaboration.

Cooperation between the IIW and the UATI and IFD (Union of International Engineering Organizations and International Federation of Documentation) was also discussed.

Twenty-six papers by authors from 10 countries were presented at the Public Session organized on the occasion of the Assembly and held on July 1st. The following aspects of the main theme of the session—"The Metallurgy of Welding" were treated by the authors:

1. Gas absorption and its influence on weld metal
2. The behaviour of welds as regards aging and caustic embrittlement
3. The metallurgy of brazing
4. The metallurgy of the welding of stainless and heat-resisting steels of ferritic, semi-ferritic and austenitic types
5. The metallurgy of the welding of non-ferrous metals
   - 5.1. Titanium and its alloys
   - 5.2. Magnesium and its alloys
   - 5.3. Aluminum and its alloys
   - 5.4. Nickel and its alloys

The papers were presented in the above groups by German rapportours and gave rise to a lively discussion.

As is now customary at IIW Assemblies, an exhibition of welding literature was organized at Essen and enabled members to see up-to-date literature on welding published throughout the world.

A catalogue of the publications exhibited for the first time at Essen has been prepared by the German Organizing Committee of the Assembly. It forms a continuation of the two catalogues dealing respectively with the Florence Exhibition and the Zurich and Madrid Exhibitions and is a valuable addition to the general bibliography which the successive catalogues of these IIW Exhibitions constitute.

Members of the Assembly had an opportunity to see 23 modern films on welding which had been lent for the occasion by 5 member countries.

Next Annual Assembly

The 1958 Annual Assembly will be held in Vienna, Austria, from June 29th to July 5th. For the public Session to be organized on the occasion of this Assembly, the following theme has been chosen: *"Welding in the Chemical Industry."* Sessions to be held within this general theme will concern (1) influence of the method of welding, of preheating and of finishing operations on the properties of welded assemblies in comparison with those of the parent metal; (2) welding of clad metals 1/m lining; (3) special problems in the welding of equipment for the chemical industry and for nuclear plants; (4) design and calculation of welded products working under high pressure and at high temperatures; and (5) typical examples of welded constructions.

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Available in these Temperatures (F.)

113	375	1000
125	388	1050
138	400	1100
150	413	1150
163	425	1200
175	438	1250
188	450	1300
200	463	1350
213	475	1400
225	488	1450
238	500	1500
250	550	1550
263	600	1600
275	650	1650
288	700	1700
300	750	1750
313	800	1800
325	850	1850
338	900	1900
350	950	1950
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TEMPILSTIK° marks on workpiece "say when" by melting at stated temperatures — plus or minus 1%.

ALSO AVAILABLE IN LIQUID AND PELLET FORM . . . WRITE "WELDING SALES" DEPT. FOR SAMPLE TEMPIL° PELLETS . . . STATE TEMPERATURES OF INTEREST—PLEASE!

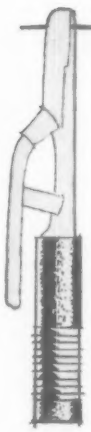
Tempil° CORPORATION 132 WEST 22ND STREET, NEW YORK 11, N. Y.

Visit our Booth #1041 at the Chicago Metal Show, November 4–8, 1957

For more details, circle No. 35 on Reader Information Card

NEW TOOL FOR THE TRADE . . .

■ Here is a handy, 24-page guide that will help you pick the right electrode for *any* job! Electrodes are identified by type, AWS grade and color coding, chemical and physical analyses and suggested uses to aid the welding engineer, purchaser, and designer. The M&T Electrode Selector has been called the "handiest practical guide to electrode selection made available in years" . . . And it's yours *free!* *Write Metal & Thermit today for a copy.*



Metal & Thermit MUREX(R) electrodes for mild, low, alloy and stainless steels, aluminum bronze, cast iron, and aluminum; SPEEDEX iron powder electrodes; and HARDEX hard surfacing electrodes are available throughout the U. S.

WELDING SUPPLIES
CERAMIC MATERIALS
ORGANIC COATINGS
TIN & TIN CHEMICALS
PLATING MATERIALS
METALS AND ALLOYS
HEAVY MELTING SCRAP

METAL & THERMIT
CORPORATION
GENERAL OFFICES: RAHWAY, NEW JERSEY

For more details circle No. 36 on Reader Information Card

PERSONNEL

Kalvelage Appointed by Ampco

The Weldrod Department of Ampco Metal, Inc., Milwaukee 46, Wis., has announced the appointment of Bernard A. Kalvelage as welding engineer.

Mr. Kalvelage formerly served as welding technician with A. O. Smith Corp., Milwaukee, where he acquired considerable experience in the use and application of Ampco Bronze Weldrod products. He is ASME Boiler Code approved for metal-arc and inert-gas welding on steel and has taught oxy-acetylene welding and brazing.

Kordwitz and Lauer Named by K-G

Two new appointments within the K-G Equipment Co. have been announced.

Norman M. Kordwitz, previously sales coordinator for K-G Equipment Co., has been appointed merchandising manager. In this capacity he is responsible for maintaining customer relations, coordinating sales efforts, merchandising and advertising programs.

Albert W. Lauer, formerly chief engineer, was appointed engineering director with the responsibility of directing new products and methods. Mr. Lauer is a member of the AMERICAN WELDING SOCIETY.

Howland Retires

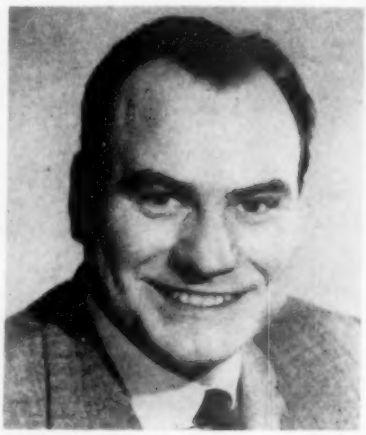
Owen L. Howland retired on June 30th as a special representative of Metal & Thermit Corp.

"Duke" Howland, for many years a prominent figure in the welding industry, joined Metal & Thermit in 1943 after serving in Washington with the War Production Board. He had previously been associated with the Hollup Corporation, a division of National Cylinder Gas, and before that with Lincoln Electric Co. From 1949 to 1955 he was sales manager of Metal & Thermit's Welding Division with headquarters first in Chicago and later in New York. In 1955 he returned to Chicago as a special sales representative to serve national accounts having headquarters in the middle west. Mr. Howland is a member of the AMERICAN WELDING SOCIETY.

Dempsey Appointed by Industry & Welding

Thomas L. Dempsey has been appointed general manager of Industry & Welding and Welding Illustrated magazine, according to an announcement by Irving B. Hexter, president of the Industrial Publishing Corp., Cleveland.

In his new post, Mr. Dempsey will



Thomas L. Dempsey

direct the over-all activities of the magazine's sales organization and editorial staff.

He is a member of the board of directors and a vice chairman of the Cleveland section of the AMERICAN WELDING SOCIETY, and is a member of the national education committee of the SOCIETY.

For the past seven years, Mr. Dempsey has been associated with the Lincoln Electric Co., Cleveland, as a sales engineer.

In addition to direct sales engineering and sales consultant work for the company, he also directed courses in the design of efficient weldments, both at the Lincoln plant, and in user company facilities throughout Ohio.

He is a graduate of Fenn college, with a bachelor degree in electrical engineering.

Scarlett Elected by United Welders

Clyde F. Kaunitz AWS, President, United Welders, Inc., Bay City, Mich., recently announced the election of Jack A. Scarlett as vice-president, manufacturing.

Mr. Scarlett was graduated from University of Cincinnati as a mechanical engineer in 1938. He has held management positions with General Motors, Seeger Refrigerator and Servel, having in all positions been associated with equipment such as special welders and automated sheet metal assembly operations similar to the machines designed and built by United Welders, Inc.

Basich Appointed by Alloy Rods

The appointment of John R. Basich to the Alloy Rods Co. sales organization, was announced recently by Mr. E. R. Walsh, III, Vice-President in Charge of Sales. Mr. Basich will be a field

John R. Basich

representative calling on customer accounts in the San Francisco and Bay areas. In addition, he will work with distributor organizations in northern California, and in the state of Washington and Oregon.

Prior to joining Alloy Rods Co., Mr. Basich was with the Consolidated Western Division of U. S. Steel in their fabrication and welding departments. His headquarters in the San Francisco area will be 26 O'Farrell St., San Francisco 8, Calif.

Goldsby, Hamilton and Lange Promoted by CB&I

Fred L. Goldsby, vice-president and formerly general sales manager, has been appointed assistant to the president, Chicago Bridge & Iron Co., Chicago, Ill.

S. C. Hamilton, formerly district sales manager, Houston, Tex., has been made a vice-president and general sales manager of CB&I, with headquarters in Chicago.

with VICKERS* Controlarc* the Versatile DC Welder

Ford Motor Company's Aircraft Engine Division was one of the first to use the Vickers Controlarc DC Welder.

At the time this versatile magnetic-amplifier-rectifier welder was first introduced, Ford had just completed a survey of all the welders on the market. From this study followed recognition of the need for a welder that would provide: better arc stability, retention of arc characteristics under line voltage fluctuations, wider current range and good performance at very low currents, quick speed of response and recovery from arc short, control of volt-ampere curve and easy remote foot control. It was evident that a *true* magnetic amplifier welder would most closely meet the special requirements of their aircraft fabrications.

Today, many companies in the aircraft industry acknowledge the excellent performance characteristics of the Controlarc, and have accepted this fine machine in the fabrication of aircraft, guided missiles and nuclear components.

From exacting aircraft requirements to simple, rugged heavy load air-cutting—the Vickers Controlarc can do a job for *you*.

WRITE TODAY for information.

Represented in Canada by:

Williams & Wilson, Limited—
Montreal, Toronto, Quebec City,
Ottawa, Windsor and Cornwall

General Welding & Industrial
Supplies, Limited—
Toronto

*Trademarks

VICKERS ELECTRIC DIVISION

VICKERS INCORPORATED a unit of Sperry Rand Corporation

1853 LOCUST STREET • SAINT LOUIS 3, MISSOURI

For more details, circle No. 37 on Reader Information Card

Fred L. Goldsby

K. W. Lange, formerly with the firm at the San Francisco Sales office, has been appointed Houston district sales manager.

Mr. Goldsby, who joined CB&I in 1927 in the Chicago Shop, has been general sales manager and a director since 1954. Mr. Goldsby attended Bradley University and the University of Illinois, from which he received a B.S. degree in Civil Engineering in 1927.

Mr. Hamilton, district sales manager in Houston since 1940, and a director of

S. C. Hamilton

CB&I since 1946, is a 1929 graduate of Iowa State College, with a B.S. degree in Civil Engineering.

JOIN NOW!

If you are interested in better welding, lower fabrication costs and increased productivity, you will gain from investment in AWS Membership. You can learn how to join by writing AMERICAN WELDING SOCIETY, 33 West 39th Street, New York 18, N.Y.

Mr. Lange joined Chicago Bridge & Iron Co. in 1941 in the Chicago Erection District and since 1947 has been in the San Francisco Sales office. He graduated from the Oregon State College in 1939 with a B.S. degree in Civil Engineering and from Yale University in 1941 with a degree of Master of Engineering.

Mr. Hamilton and Mr. Lange are both members of the AMERICAN WELDING SOCIETY.

Burke and Townsend Appointed by Tweco

Tweco Products, Inc., Wichita, Kan., announces the appointment of Mr. Thomas A. Burke, Jr. as the North Central District manager. Mr. Burke will have charge of sales in the states of

Thomas A. Burke

James L. Townsend

Illinois, Indiana, Michigan, and Wisconsin. Before joining Tweco, Mr. Burke was with the Machinery and Welder Corp. as a district salesman.

The company also announces the addition of James L. Townsend to the administrative staff of the Wichita office. Before joining Tweco, Mr. Townsend was a student at the University of California at Berkeley, where he graduated with a degree in Business Administration.

Mr. Townsend is a member of the AMERICAN WELDING SOCIETY.

OBITUARY

Noah A. Kahn

Noah A. Kahn, head metallurgist at the New York Naval Shipyard, died on Thursday, June 20th while attending the American Society for Testing Materials Annual Convention in Atlantic City.

Mr. Kahn graduated in Chemical Engineering from Lehigh University in 1922. After 4 years as Research Metallurgist with the Bethlehem Steel Co., he took up postgraduate work at Washington University where he received the Degree of Master of Science in 1927. Since 1927, he has been with the New York Naval Shipyard where he held the responsible position of head metallurgist. In 1944, he received the Meritorious Civilian Award for distinguished service to the Navy.

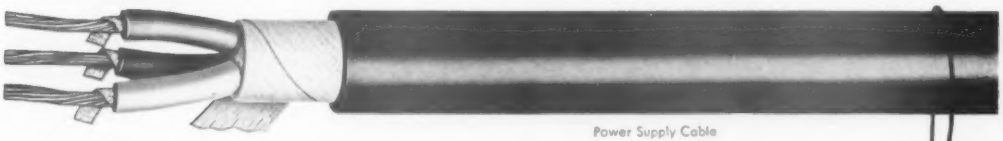
Mr. Kahn was author of numerous papers covering various aspects of nondestructive testing and physical metallurgy. His work on brittle fracture

Noah A. Kahn

phenomena in ship plate and on notch-toughness of weld deposits has been published in the *Welding Research Supplement*. He was a frequent speaker before technical groups and societies, and served on The Pressure Vessel Research Committee of the Welding Research Council. He was a member of several technical societies.

Mr. Kahn is survived by his wife, Helen, and two daughters, Naomi and Carol.

If it's worth engineers' time...



...it's worth engineered cable

Belden
WIREMAKER FOR INDUSTRY
SINCE 1902
CHICAGO

4-W

Magnet Wire • Lead and Fixture Wire • Power Supply Cords, Cord Sets and Portable Cord • Aircraft Wires
Welding Cable • Electrical Household Cords • Electronic Wires • Automotive Wire and Cable

For more details, circle No. 38 on Reader Information Card

NEW LITERATURE

Filler Metal Comparison Charts Available

The AMERICAN WELDING SOCIETY announces the publication of a very comprehensive set of welding rod and electrode comparison charts contained in a 24-page, 8½ x 11-in. booklet. The brand names of 61 companies are included, 12 AWS-ASTM specifications are involved and two indexes list brands as well as manufacturers' names.

This series of filler metal comparison charts was developed to supply an international demand for answers to the following questions:

What classification is Brand X?

Does Brand X come within the same classification as Brand Y?

Who makes it? Who distributes it?

Over twelve months of research were necessary before this information could be obtained, checked, classified and assembled. The magnitude of the task can be judged by the twelve AWS-ASTM classifications involved: Mild Steel Electrodes, Iron and Steel Gas Welding Rods, Covered Aluminum Electrodes, Covered Stainless Steel Electrodes, High Tensile and Low-Alloy Steel Electrodes, Copper Alloy Electrodes, Copper Alloy Welding Rods, Brazing Filler Metal, Bare Stainless Steel Welding Rods and Electrodes, Bare Aluminum Welding Rods and Electrodes, Covered Nickel Alloy Electrodes and Tungsten Electrodes.

This booklet of filler metal comparison charts is the most complete ever assembled. Sixty-one manufacturers cooperated by supplying data on their products. It should prove invaluable to those who specify material or who have the responsibility of selecting welding rods and electrodes which come within a given classification.

One very important feature of the booklet is the ease with which brand identification can be made. An alphabetical index lists the brand names and another index lists the full names and addresses of manufacturers.

Copies can be obtained from the AMERICAN WELDING SOCIETY, 33 West 39th St., New York 18, N. Y. Price $2.00 postpaid.

Resistance Welders

New Bulletin 8-313, the Taylor-Winfield Corp., Warren, Ohio, describes resistance welders designed to mass-produce electrical contact, conductor, and terminal assemblies. Illustrated are samples of welded assemblies, special welding equipment and tooling required for mechanized handling. For your free copy, circle No. 39 on Reader Information Card.

Welding Distortion

A 48-page booklet entitled Control of Welding Distortion is now available from the Institute of Welding, 54 Princes Gate, London, S. W. 7, England.

The booklet outlines the causes of distortion, and describes the methods by which it may possibly be avoided, controlled, or corrected in practice. It is offered as a practical guide for all those who use arc and oxyacetylene welding processes.

For your copy, write to the Institute of Welding at the above address and enclose 5 *s*. Postage will be free.

Wall Chart

The Stulz-Sickles Co., Port Ave. at Julia St., Elizabeth, N. J., has prepared for distribution a 28- x 45-in. wall chart which depicts actual sizes of the 23 different shapes of "Manganal 11%–13½%" manganese-nickel steel wedge bars. The chart also lists complete dimensions and estimated weights per foot of Manganal flats, rounds, squares, and triangle applicator bars, in addition to illustrations of the five sizes of special shape applicator bars and the Wing-Ding individual slip overs.

For your free copy, circle No. 40 on Reader Information Card.

Welding Nozzles

Literature entitled "When You Buy Nozzles—Are You Sacrificing Performance?" is now available from the Linde Co., division of Union Carbide Corp. The manufacture and testing of "Oxweld" nozzles are described. For your free copy, circle No. 41 on Reader Information Card.

Engineering Data Sheet

A new two-color 8½ × 11 two-page Engineering Data Sheet (No. 5) listing grinding wheel recommendations for finishing overlays of Colmonoy hardsurfacing alloys is now available from Wall Colmonoy Corp., 19345 John R St., Detroit 3, Mich.

The new data sheet lists in tabular form recommended wheels for use on Colmonoy nickel-base, cobalt-base and iron-base alloys.

For your free copy, circle No. 42 on Reader Information Card.

Welding Positioners

Aronson Machine Co. announces that a 12 page bulletin No. HTS57 is now available featuring eight (8) distinctive models ranging in capacities from 5000 to 160,000 lb. Complete data on each model is given plus a page of comprehensive specifications and quality features including the following: Precision rotation, positive ground current conduction, and a wide range of optional extras—over 50 different tables from which to choose.

For your free copy, circle No. 43 on Reader Information Card.

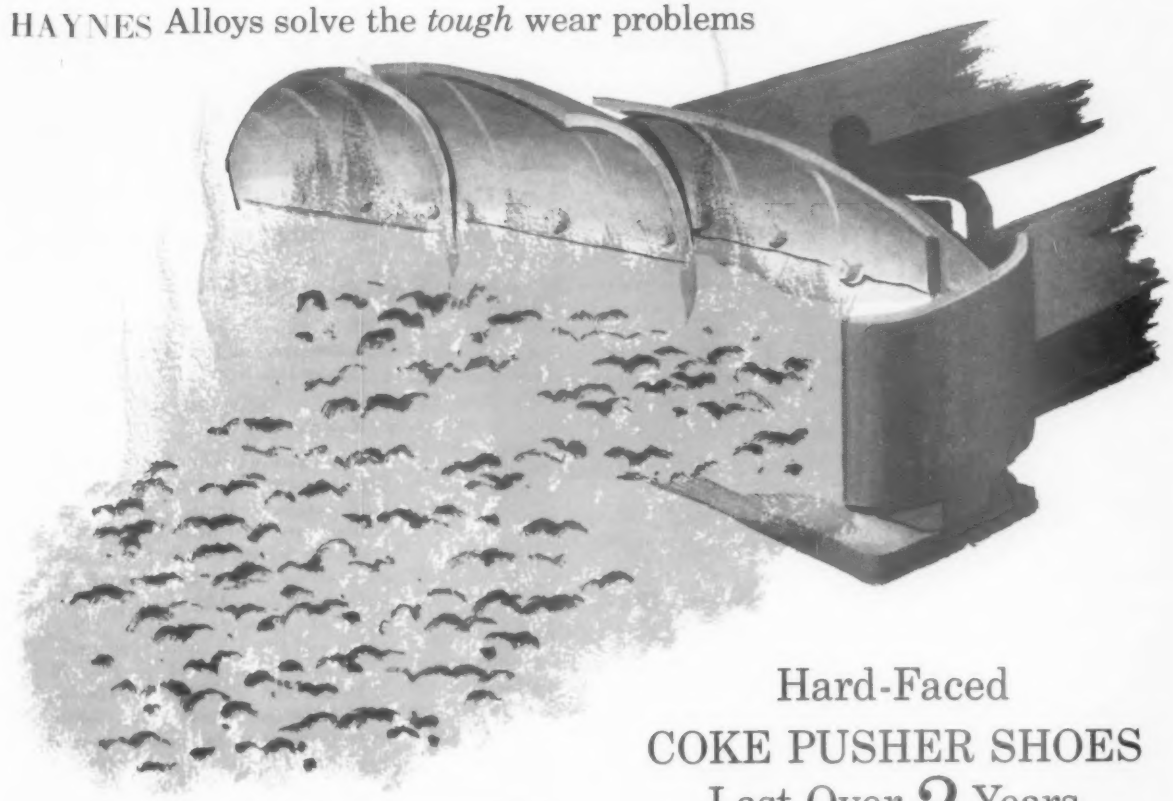
Arc Welding Manual

A new instruction guide to learning the basic skills of arc welding has been published by The James F. Lincoln Arc Welding Foundation, Cleveland 17, Ohio. The 40-page booklet, entitled "Manual of Instruction for Arc Welding," contains explanatory diagrams, illustrations and ideas for useful projects. The booklet can be used for self-instruction or as a text for a basic course in arc welding.

The manual discusses basic welding techniques and skills and topics such as the effect of heat on metals; common, high carbon, alloy and tool steels and their preparation for welding, brazing, cutting, soldering, hardsurfacing, pipe welding and sheet metal welding as well as welding supplies and equipment. Also included are pictures of useful equipment and tools that can be made by welding.

For your copy, send 50¢ to The James F. Lincoln Arc Welding Foundation, Cleveland 17, Ohio. The manual will be mailed postpaid.

HAYNES Alloys solve the *tough* wear problems



Hard-Faced COKE PUSHER SHOES Last Over 2 Years

Resisting severe abrasion, heat, and thermal shock produced by riding over the coke-covered floor of 1800-deg. F. ovens—these shoes hard-faced with HAYNES STELLITE alloy No. 1 lasted over two years. Ordinary steel shoes wore out in two months.

Whatever your wear or abrasion problem, there is a HAYNES hard-facing alloy especially made to combat it. There are 18 HAYNES hard-facing alloys . . . a wide selection that assures economical protection from the most severe conditions of heat, corrosion, erosion, or wear. For the complete story write for descriptive literature or contact our nearest sales office. HAYNES STELLITE COMPANY, Division of Union Carbide Corporation, General Offices and Works, Kokomo, Indiana.

These shoes, hard-faced with HAYNES STELLITE alloy No. 1, resist abrasion from the coke particles and the lining of the oven floor. The hard-faced deposit does not chip or spall under the thermal shock of returning from 1800 deg. F., in the oven, to ordinary atmospheric temperatures.

HAYNES ALLOYS

HAYNES STELLITE COMPANY

Division of Union Carbide Corporation

Kokomo, Indiana

UNION CARBIDE

"Haynes," "Haynes Stellite" and "Union Carbide" are registered trade-marks of Union Carbide Corporation.

For more details, circle No. 44 on Reader Information Card

Alloy News

The Wall Colmonoy Corp., 19345 John R St., Detroit 3, Mich., announces the availability of Volume 2, Number 4 of Colmonoy Alloy News. It contains a number of articles on brazing and hard surfacing.

For your free copy, circle No. 45 on Reader Information Card.

A-C Welders

Publication GEC-1259C, four pages, illustrated, includes product features, specifications, power requirements, operating data and list of optional features for General Electric a-c welders in 300-, 400- and 500-amp ratings. Available from the General Electric Company, Schenectady 5, N. Y.

For your free copy, circle No. 46 on Reader Information Card.

Flash Welding

The Taylor-Winfield Corporation of Warren, Ohio, has released their four-page booklet, No. 575, entitled "Weld-It." An article describing "flash welding automobile frames" is included. Bulletin SP-4A, describing hydraulic controls for flash welders, is also mentioned in the booklet.

For your free copy, circle No. 47 on Reader Information Card.

Safety

The Health and Safety Sub-Committee of the Institute of Welding is preparing a series of information sheets under the general title of *Accidents and their Prevention*, and the first of these has now been published. It deals with the dangers of carelessly releasing free oxygen gas into confined spaces.

These information sheets are designed to encourage work people to be more conscious of the common causes of accidents in the use of welding and cutting equipment. They do not replace the Institute's publication *Health and Safety in Welding*, which is a reference book.

For your free copy, circle No. 49 on Reader Information Card.

Stainless Steel

A 12-page issue of Eutectic's semi-monthly Technical Information Digest (TIS 2818) entitled "Fabricating the Stainless Steels," is now available from Technical Information Service, Eutectic Welding Alloys Corp., 40-40 172nd St., Flushing 58, New York, N.Y.

The manual discusses the metallurgy of the different stainless steels. Data are developed to help the welder prevent weld weakening intergranular corrosion thus preventing reduced resistance of the stainless steel to aqueous, corros ve solutions. Welding techniques and alloy selection are given for the "low heat input" process which minimizes the warping, distortion, cracking, embrittlement and other undesirable metallurgical changes in the base metal which occur with conventional high heat welding materia s.

For your free copy, circle No. 50 on Reader Information Card.

X-Ray

A series of portable, industrial X-ray equipment for radiographic inspection of castings, welds, and assemblies is illustrated and described in a 2-color, 4-page folder that has just been released by Mitchell Radiation Products Corporation, 128 East Washington Street, Norristown, Pa. The three units of the MS series presented—with respective ranges of 55–200, 70–260, 70–300—all reportedly have built-in high tension transformers, color-coded technique charts on the face of the control panels, and protective devices for overloads, high voltage, excessive voltage and excessive oil temperature.

For your free copy, circle No. 51 on Reader Information Card.

ADVANCED
"Jet Flux" System
auto dispenser and brazing liquid
ALL-STATE
Silver Brazing
alloy dispenser for Mr. Fix-It
STAINLESS
Solder Kit
for 10,000 to 28,000 psi T
Melds smoothly into brazing operations. Permits elimination of paste flux. Ruggedly compact, sized for work-week without refilling. Attach to fuel line on truck or station . . .
see your DISTRIBUTOR for demonstration
Includes wire and flux. The only good way to keep silver solder safe and ready for maintenance and service men. Six choices from 3 kinds, 2 lengths. Save time and money.
buy from DISTRIBUTOR he keeps stocks
All-State's greatest Solder. Useable on stainless, monel, brass, bronze, steel, copper. Contains 6 ft. No. 430 Silver-Bearing Stainless Solder and supply of flux. 1 job saves cost.
buy by the doz. from DISTRIBUTOR local stock
All-State Welding Alloys Co., Inc. White Plains, N. Y.
ALL-STATE ALLOYS AND FLUXES
REQUEST COMPLETE LIST OF THESE PRODUCTS FOR PROBLEM SOLUTIONS
For more details, circle No. 48 on Reader Information Card

REVIEWS
OF NEW BOOKS

Design of Welded Structures

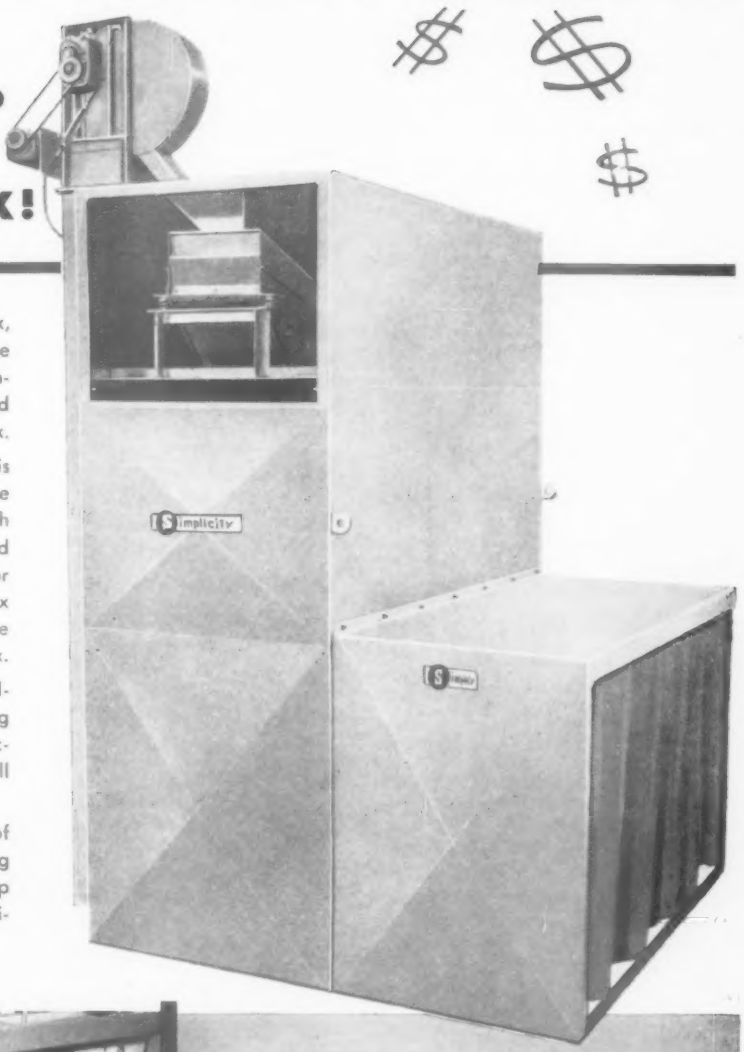
Design of Welded Structures with Practical Applications (Rešení Svarovaných Konstrukcí A Otázky Praxe). Vol. 3 of Priručka Svarování, edited by Prof. Frantisek Faltus and 10 collaborators. Published in Czech by Statni Nakladatelství Technické Literatury, Prague, 1955, 600 pages. 45.30 Kčs (about $6.30).

This is a good theoretical and practical textbook for engineering students. The book is divided into three parts. In the first part there are three chapters on design of welded connections, design of welded structures and design of pressure vessels. The second part applies design principles to simple machine components, welded electrical machinery, railroad rolling stocks, locomotives and rail joints, steel tubing and piping, bridges, structures and repair work. The third part deals in the non-destructive and mechanical testing, health and safety.

(Reviewed by Dr. G. E. Claussen, Metals Research Laboratories, Electro-metallurgical Co., Niagara Falls, N. Y.)

THROWING MONEY AWAY?

YOU ARE, IF YOU SCRAP SPILLED AND FUSED FLUX!

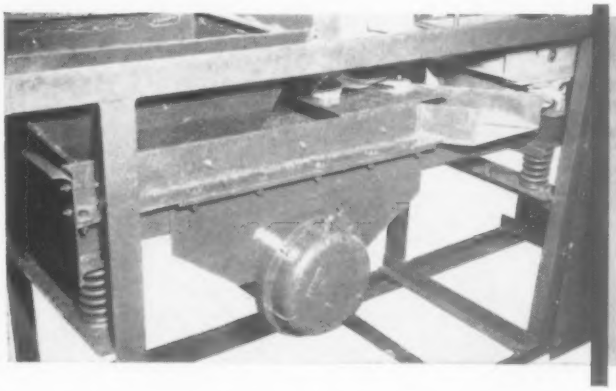


When you discard spilled and fused flux, you're throwing profits to the wind. A large automotive plant solved this problem by installing the Simplicity Flux Reclaim Unit, and saving $5,000 a month salvaging used flux.

Sound good? It should, if your plant is equipped with submerged arc welders. The Simplicity Flux Reclaimer is designed to crush used flux, remove metal particles, dust and fines, and give you refined flux ready for re-use. Mixed in proper ratio with new flux (depending upon type of work) welds are obtained equal to those made with new flux.

Equipped with a two surface vibrating feeder, bucket elevator, double deck vibrating screen, 15" x 9" crusher and two magnetic-pulleys, the Simplicity Flux Reclaimer will more than pay its own way.

Complete installation drawings and prices of these SIMPLICITY units may be had by writing directly to the factory . . . a logical first step in determining ALL the money-saving possibilities these machines may hold for you.



View of 12" x 4'9" two surface oscillating feeder, showing side discharge for removing scrap, metal particles and other foreign objects.

195

SALES REPRESENTATIVES IN ALL PARTS OF THE U.S.A.

FOR CANADA: Simplicity Materials Handling Limited, Guelph, Ontario.

FOR EXPORT: Brown and Sites, 50 Church Street, New York 7, N. Y.

Simplicity
TRADE MARK REGISTERED

ENGINEERING COMPANY • DURAND 23, MICHIGAN

For more details, circle No. 52 on Reader Information Card

NEW PRODUCTS

Welding Positioner

Model 21TS completely fills the need for a fully-automatic positioner to match the latest high precision production welding processes for welding titanium, according to the manufacturer, Aronson Machine Company, Arcade, New York. The "Titanium Special" is said to provide a gas-tight seal plate under the 60-in. round 8-slot, precision

machined table. The seal plate is 64-in. in diameter and allows the user to place a plastic gas-tight dome over table and workpiece to weld in gaseous atmosphere. The positioner features precision controlled rotation at variable speed and fast positioning, powered tilting and powered elevating, all preset in an electrical panel.

The load capacity is 5000 lb with center of gravity 6 in. above table and 4 in. off-center and provides 20,000 lb-in. rotation torque.

For more details, circle No. 53 on the Reader Information Card.

Flowmeters

A new line of dual-range flowmeters is now being marketed by Air Reduction Sales Co. Known as the 1600 Series, they are designed for inert-gas welding, flushing molten metals, laboratory service, and many other industrial applications where accurate control and constant visual check of flow rate are required.

According to the manufacturer, flow ranges of the new flowmeters are sufficiently wide to meet gas demands formerly requiring more than one metering device. Rapid in-service switching from either flow range to the other is done by means of a piston-type selector valve. Flow rate within either range is controlled by a sensitive needle valve. Accuracy is maintained under all service conditions and is not affected by back pressures.

The series includes seven direct-reading flowmeters, each for a specific gas, and one general-purpose flowmeter, provided with calibration curves, which will meter any of five gases. A combination of two or more flowmeters can be used to proportion a mixture of gases.

The new flowmeters can be attached to cylinder or pipeline regulators, directly to pipelines, or they can be bench or wall mounted by means of the special mounting clamp supplied.

For more details, circle No. 54 on Reader Information Card.

Oxyacetylene Welding Outfit

An improved model of its Prest-O-Lite No. 420 welding and cutting outfit capable of welding up to $^3/_8$-in. and cutting up to 2 in. has been introduced by Linde Co., Division of Union Carbide Corp.

This outfit still includes the Prest-O-Lite No. 420 blowpipe which welds, cuts, heats and brazes without a cutting attachment. However, some changes now make the blowpipe even easier to use. According to the manufacturer, the cutting oxygen lever has been moved to the top of the handle where it can be turned on or off with the thumb. A green plastic ring has been placed around the oxygen valve and a red ring around the acetylene valve for quicker and more positive identification.

Besides the No. 420 blowpipe and R-412 and R-413 regulators, the new model Prest-O-Lite No. 420 Welding and Cutting Outfit includes: four interchangeable tips (3 welding, 1 cutting), 12 $^1/_2$-ft length twin hose, goggles, friction lighter, wrench, and complete instructions.

For more details, circle No. 55 on Reader Information Card.

Hard Surfacing

Dril-tec 86, 88, and 89, hard-surfacing alloys depositing tungsten carbides on steel, cast iron or copper alloys without fusion are now available from Eutectic Welding Alloys Corp., 40-40 172nd Street, Flushing 58, New York, N. Y.

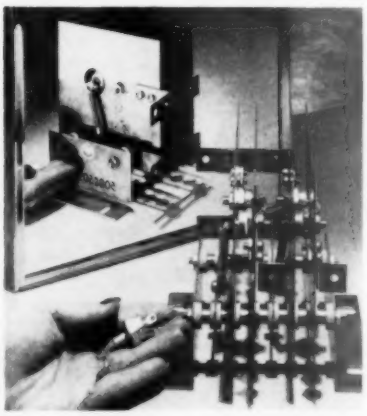
According to the manufacturer, all three Dril-Tec rods are composite, heterogenous, preformed hard overlaying materials for providing cutting and/or wear and abrasion surfaces on equipment used for drilling, boring, reaming, earth removing, burning shoes, coring tools and bucket teeth.

For more details, circle No. 56 on Reader Information Card.

Silicon Rectifiers

Two new silicon power rectifiers (Types 302 and 303) are now available from the Westinghouse Electric Corporation. Models 302 and 303 are hermetically sealed silicon rectifying cells providing d-c currents up to 35 amp and 22 amp halfwave, respectively, with a maximum peak inverse voltage up to 600 volts.

According to manufacturer, the for-



ward voltage drop of cell 302 will not exceed 0.9 v at a forward current of 10 amp in ambient temperatures of 25 to 35 deg C. Reverse leakage of the cell is a maximum 20 ma at rated peak inverse volts and maximum temperature. Maximum operating junction temperature is 190 deg C. For cell 303, the forward voltage drop will not exceed 1.2 v at a forward current of 10 amp in an ambient temperature of 25 to 35 deg C. Reverse leakage is a maximum 10 ma at rated peak inverse volts and maximum temperature. Maximum

Why it pays to specify Westinghouse **IGNITRON TUBES,** the "industry standard"

Westinghouse invented and produced the first Ignitron tube. Since then, constant improvements have maintained Westinghouse leadership in the Ignitron field—improvements that are today's accepted industry standards:

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- **Stainless steel envelopes for corrosion-free long life.**
- **Inner cylinder in direct contact with cooling water.**

The wide acceptance of Westinghouse Ignitron Tubes by the welding industry is proof of their superior quality and performance. It will pay *you* to use Westinghouse Ignitrons in both new and existing welding equipment. For your convenience they are readily available through Westinghouse Distributors everywhere.

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operating junction temperature is 190 deg C. On both cells, the plated rectifier case is the positive (cathode) terminal and has a threaded 1/4—28 stud for through mounting. Each cell, weighing 0.65 oz, is shipped with hex nut, lock washer and flat washer, two 0.003-in. thick mica washers and an insulating bushing. The 302 and 303 rectifiers are also available in complete bridge assemblies.

For more details, circle No. 58 on Reader Information Card.

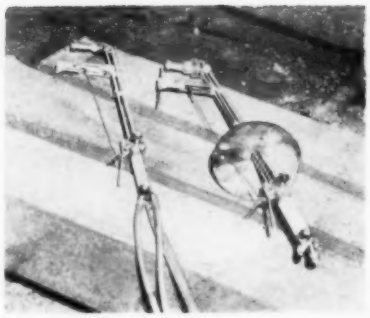
Scarfing Torch

A new three-hose scarfing torch has been developed by National Cylinder Gas Co., Chicago, for heavy duty work where large rates of metal removal are desired. The manufacturer reports that it has been successfully field tested for a year now at major mills in both the Pittsburgh and Chicago areas.

The torch is said to permit independent control of the preheating and the scarfing oxygen flows.

Additional features of the new torch include: (1) an improved guard (removable and replaceable) over the head of the torch and an improved skid ring on the end of the tip—both of modern wear-resistant alloys; (2) improved balance specifically engineered for scarfing work; and (3) unusually convenient placement of scarfing lever, preheat oxygen adjustment, and acetylene valve with respect to operators' hands and stance.

For more details, circle No. 59 on Reader Information Card.

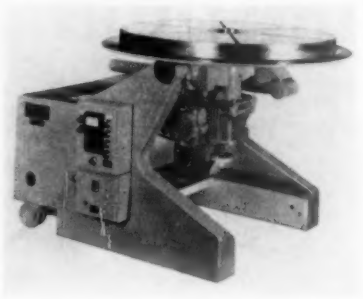


Welding Positioner

A new precision welding positioner known as Model WP-2-S was recently announced by the Harnischfeger Corporation, to serve the precision welding requirements of aircraft and guided missile fabricators.

According to manufacturer, one of its new features is an extended stationary table directly under the revolving face plate which provides a rigid base for the support of an inert-gas dome or working enclosure. Table speeds of 0.02 to 2.0 rpm are obtained through an electronic d-c motor with variations infinitely controlled to within 1%. A tachometer calibrated in rpm is offered as standard equipment.

The table-tilting mechanism uses a high-efficiency Saginaw ball-bearing screw driven by a worm gear reducer, completely enclosed to prevent damage from foreign matter or weld spatter. Degree of tilt is shown on a positive acting indicator.



WP-2-S is available either as a stationary machine or with casters.

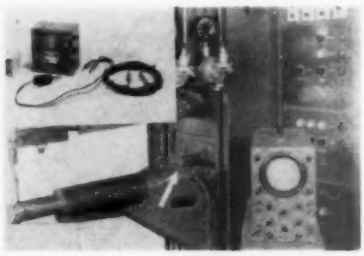
A specially designed rotating ground connection at the end of the table spindle insures adequate current capacity for automatic welding applications.

Table flatness and run out are held to extremely close tolerances.

For more details, circle No. 61 on Reader Information Card.

Resistance Welding

According to the manufacturer, when connected to an oscilloscope the secondary current patterns of any conventional single-phase or three-phase machine can be observed for weld timing or counting verification, heat balance, etc. Likewise, when connected to a d-c amplifier and recording oscillograph, high current oscillograms can be permanently recorded. Window illustration shows a complete unit...arrow points to a device in actual use.



Sciaky Bros., Inc., 4915 W. 67th St., Chicago 38, Ill., are now marketing a secondary current pickup device which is said to be very useful to a quality control or maintenance program with resistance welding equipment.

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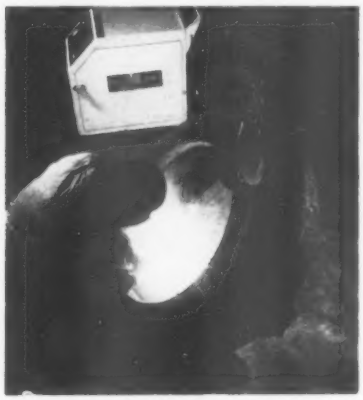
Hard Surfacing

Two new hard-surfacing wires for semiautomatic welding have been released to industry by the American Manganese Steel Division of American

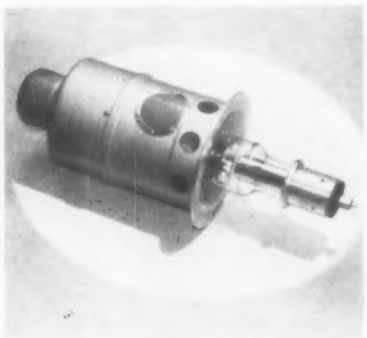


Brake Shoe Company. One of these tubular electrodes, designated S/A manganese, is recommended for manganese steel buildup and repair applications, while the other wire, known as S/A 53, is for hardsurfacing to resist wear and impact. Both wires are $^{3}/_{32}$ in. diam and can be operated through the Amsco MF welder.

For more details, circle No. 63 on Reader Information Card.

X-ray

Machlett Laboratories, Inc., Springdale, Conn., announces the EG-180R an end-grounded, forced-air cooled X-ray tube providing high-power continuous loading. Neither hose lines nor heat exchangers are required. Full power may be used at ambients as high



as 135° F. According to manufacturer, the EG-180R normally requires two minutes or less for morning warm-up; thereafter individual exposures require less than $^{1}/_{2}$ minute warm-up time.

EG-180R is available in two versions, EG-180RB a beryllium window tube providing a 40° cone of radiation and EG-180RX a nickel window tube providing a 360° band of radiation.

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Hard-Surfacing Alloy

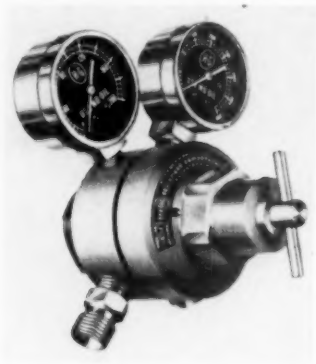
The availability of a new hard, machinable nickel-base hard-surfacing alloy containing chromium borides is announced by Wall Colomony Corp., 19345 John R St., Detroit 3, Mich.

Designated Colmonoy No. 56, the new material is said to provide protective hardness in the range of 50 to 55 Rockwell C, yet is machinable with carbide tools. Developed especially to provide the particular properties of high hardness and machinability frequently specified for extrusion screws used in the plastic and rubber industries, the alloy is also suitable for wear proofing such parts as pump and valve components, dies and guides of various types.

For more details, circle No. 66 on Reader Information Card.

Gas Regulator

The K-G Equipment Co., Inc. a unit of Air Products, Inc., Allentown, Pa., announces a new gas regulator,



known as the "K-G Jeep."

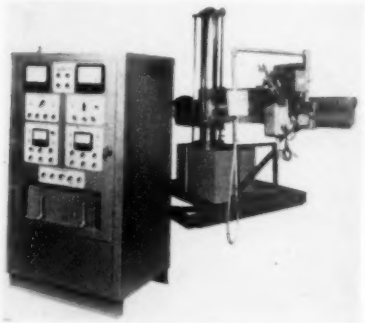
According to manufacturer, the small regulator is designed for medium to light-duty service and is approved by the Underwriters Laboratory. The clear anodized body and back cap are made of high strength forged aluminum, with a tensile strength of 68,000 psi. High pressure gages are graduated to 4000 psi, adding a 1000-lb safety factor.

The regulator is also said to contain only two replaceable parts, a factor which encourages effective repair in the field. No special tools are required. High-pressure parts—seats, pins, stems, springs, "O" rings and back caps—are interchangeable with the K-G 1200 series regulators.

For more details, circle No. 68 on Reader Information Card.

Fusion Welder Control

The Weltronic Co., Detroit, Mich., announces their new tungsten-inert-gas fusion welder control. The unit is sold under the trademark of Weltronarc and is reportedly an advance in the automatic control of precision fusion welding. According to the manufac-



turer, Weltronarc control was designed to meet the unusual welding requirements encountered in jet engine fabrication and to master the problems of production welding of hard-to-weld alloys.

Contained within one central housing are the arc power supply, the automatic arc-length control, the regulated wire and carriage drives, the gas and water controls and the timer sequence.

For more details, circle No. 69 on Reader Information Card.

Flux-Cored Wire

A new flux-cored version of EutecRod 157, a high strength silver-bearing lead-free alloy for stainless steel and other base metals, has been announced by the Eutectic Welding Alloys Corp., Flushing, New York.

Called EutecRod 157B, this wire is a "solder-type" alloy in coil form.

Versatile EutecRod 157-B, available in $\frac{1}{8}$", $\frac{1}{16}$", and $\frac{3}{64}$" in. diameters, is adaptable to all common heating methods including flameless resistance, induction and transformer type soldering gun techniques.

According to the manufacturer, it is applicable for all types of joints in stainless-steel fabrication and for dissimilar metal joining.

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For full details on this project, and for complete information on the cost and time-saving Arcair Model H-3 Torch, write today.

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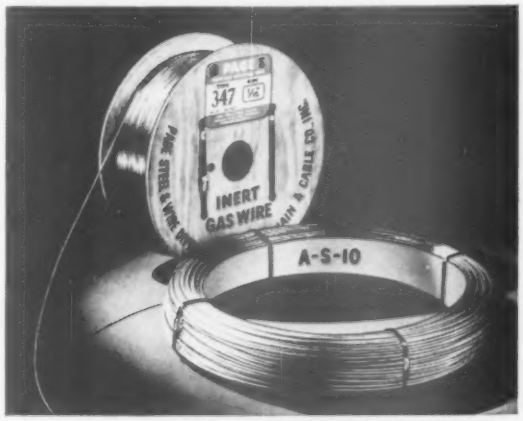

BARE ELECTRODES

PAGE Bare Electrodes are available in any carbon from Armco to high carbon (.70-.84).

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Welding Wire in Coils

PAGE A-S Automatic Welding Wire is regularly furnished in layer-wound coils with cardboard liner, four Signode straps for easy coiling and unwinding —palletized as necessary.

Gas Rod Packing

PAGE Gas Welding Rods are supplied in 36" lengths in 50-lb. bundles, paper and burlap-wrapped. Also in burlap-wrapped coils and 150-lb. (approx.) reels. Stainless rods also available in 10-lb. fibre-board cartons.

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- **Welding Rod Comparison Chart**

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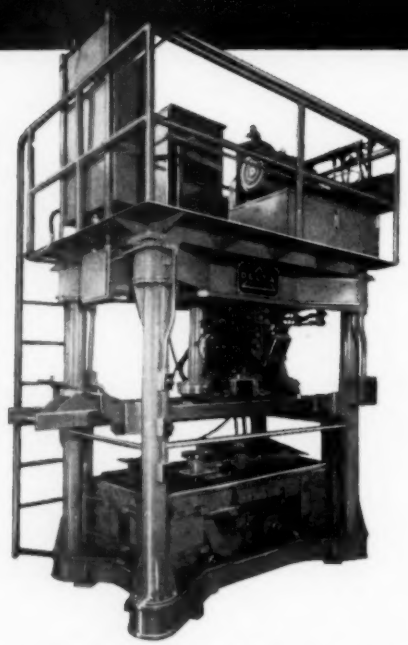

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9	34	59	84	109	134
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11	36	61	86	111	136
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7	32	57	82	107	132
8	33	58	83	108	133
9	34	59	84	109	134
10	35	60	85	110	135
11	36	61	86	111	136
12	37	62	87	112	137
13	38	63	88	113	138
14	39	64	89	114	139
15	40	65	90	115	140
16	41	66	91	116	141
17	42	67	92	117	142
18	43	68	93	118	143
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SUPPLEMENT TO THE WELDING JOURNAL, SEPTEMBER, 1957

ARREST OF BRITTLE FRACTURES IN WIDE STEEL PLATES

Program undertaken to investigate behavior of welded crack-arrester details which might be used under service conditions

BY R. J. MOSBORG, W. J. HALL AND W. H. MUNSE

SUMMARY. This paper describes an investigation which is concerned with an evaluation of various devices designed to arrest the propagation of brittle cracks. In the tests, brittle fractures are initiated by driving a wedge into a notch at the edge of steel plate specimens. The fracture propagates across the specimen until it encounters the arresting device. In order to evaluate the arresters, the tests are conducted at various combinations of temperature and stress.

Most of the work conducted to date has been concerned with the behavior of welded crack arresters composed of a strake of tough material butt welded so as to form an integral part of the structure. These tests indicate that, under certain conditions, strakes of tough material will arrest a propagating brittle crack. General observations from tests of welded arrester specimens, as well as from a few riveted arrester specimens, are presented.

Introduction

Object and Scope

During World War II, when brittle fracture became a serious problem in welded merchant ships, there was an immediate need for a means of reducing the probability of major ship structural failures. As a result, a method of arresting cracks was devised for structures already built. This consisted of slotting the main plate of the structure and riveting a doubler plate over the slot. Although this device usually worked satisfactorily, it was difficult to seal against leakage and, when used in tankers, was particularly hard to clean. In general, riveted arresters have been incorporated in ship construction since the war; a currently used detail consists of a riveted lap joint. It is likely that a limited number of riveted arresters will continue to be used in welded ship construction until dependable information becomes available on other types of large-scale arresters.

Laboratory studies have shown that for a given specimen geometry, once a brittle crack has been initiated and is propagating, it may be arrested by sufficiently reducing the average stress on the specimen or by adequately increasing the temperature of the material. However, from the practical point of view, control over the stress and temperature may be neither structurally feasible nor economical, particularly in large-scale structures which may be subjected to wide ranges of stress and temperature during service.

At present two other approaches to the problem of controlling brittle fractures in large-scale structures can be considered. These consist of (1) the use of a tough material throughout the entire structure to prevent the opportunity for brittle-fracture initiation and propagation or (2) the use of tough material butt welded in the structure at selected locations to stop cracks that might be propagating. Economic considerations may often dictate the approach to be used.

The program described in this paper was undertaken to investigate the behavior of welded crack arrester details that might be used under service conditions. In particular, the possibility of incorporating a strake of tough material or perhaps a tough weld as an integral part of the structure was studied. In the early stages of the program small-scale laboratory specimens were employed to determine whether this type of welded crack arrester would be feasible. After this preliminary work the primary emphasis was placed on the study of 6-ft wide specimens. This specimen was adopted because it was a convenient size and because it was felt specimens of this size might help in obtaining information which could more easily be related to full-scale conditions. A few riveted crack arrester specimens, fabricated according to a detail for which there was a large amount of service information, were tested to provide a basis for comparison. However, most of the program has been concerned with an investigation of welded arresters.

While this program is most directly related to ships, the principles studied in these tests could be useful in other structures (pipe lines, storage tanks, pressure vessels, etc.) where brittle fractures have occurred.

R. J. Mosborg, and W. J. Hall are Assistant Professors of Civil Engineering, and W. H. Munse is Research Professor of Civil Engineering, University of Illinois, Urbana, Ill.

Presented at 1957 AWS National Spring Meeting in Philadelphia, Pa., April 8–12.

CITY & ZONE STATE

Table 1—Chemical Composition and Mechanical Properties of Steels

(*a*) Chemical composition

Steel	Chemical Composition, % C	Mn	P	S	Si	Cu	Cr	Ni	Al	Mo	Va
E	0.21	0.34	0.019	0.030	0.01	0.18	0.12	0.19	0.003	..	..
T	0.11	0.84	0.036	0.015	0.28	0.32	0.50	0.99	0.09	0.53	0.095
X	0.20	0.76	0.019	0.040	0.03	0.04	0.02	0.16	0.002	..	..
Z	0.18	0.42	0.013	0.031	0.02	0.23	0.07	0.14	0.003	..	..

(*b*) Mechanical properties*

Steel	Yield strength, psi	Ultimate strength, psi	Elongation in 2 in., %	Reduction of area, %
E	32,100	64,900	35.8	56.7
T	111,900†	126,600	22.0	69.1
X	34,900	66,700	39.0	64.8
Z	34,700	68,100	36.5	57.6

* From Standard 0.505-in. diam specimens taken parallel to direction of rolling.
† Based on 0.2% offset.

Materials and Specimens

In order to evaluate various arrester devices, a starter material which would initiate and propagate a brittle crack under laboratory conditions was required. Two heats of rimmed steel (designated as steels E and Z) with Charpy V-notch 20 ft-lb values at about +70° F were available and were used to fabricate the riveted-arrester specimens and the portion of the welded-arrester specimens in which the crack was initiated. For the arresting material in the welded specimens, a steel possessing high strength and ductility (large energy absorbing capacity) was required. One of the steels readily available for this purpose at the beginning of the program was a low-alloy steel known as "T-1" (designated herein as Steel T). The mechanical properties and chemical composition for each of these steels are given in Table 1.

Two sizes of specimen, composed of inserts welded to long pull plates, were considered. The 2-ft wide specimens consisted of $^3/_4$- x 18- x 24-in. inserts butt welded to $^3/_4$-in. thick pull plates to provide a total specimen length of 6 ft. The 6-ft wide specimens usually consisted of $^3/_4$- x 54- x 72-in. inserts butt welded to 1-in. thick pull plates to provide a total specimen length of approximately 18 ft. All material was oriented with its direction of rolling parallel to the specimen axis and transverse to the direction of crack propagation.

The riveted arrester specimens contained a doubler plate which was riveted to one side of the main insert plate. The doubler plate was approximately the same length as the insert plate in the 2-ft wide specimens. However, it was 99 in. long in the 6-ft wide specimens so that it could be bolted to each pull plate to develop more fully the desired load in the doubler. These specimens are shown in Fig. 1. The

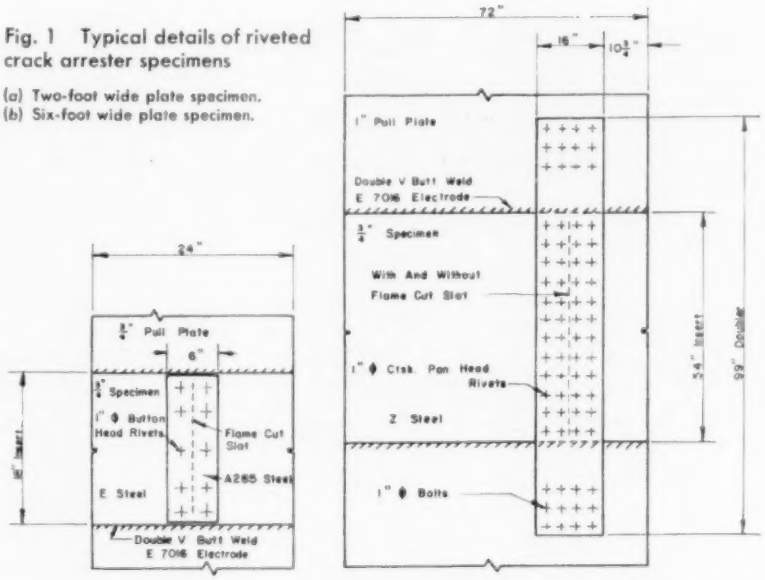


Fig. 1 Typical details of riveted crack arrester specimens

(a) Two-foot wide plate specimen.
(b) Six-foot wide plate specimen.

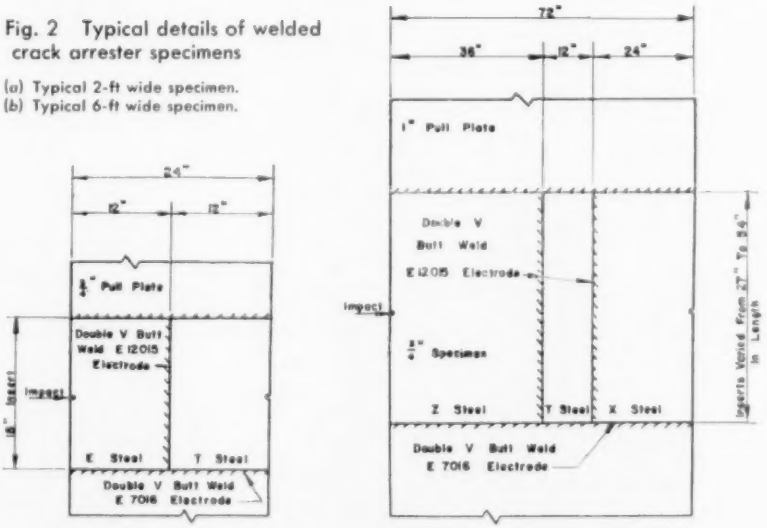


Fig. 2 Typical details of welded crack arrester specimens

(a) Typical 2-ft wide specimen.
(b) Typical 6-ft wide specimen.

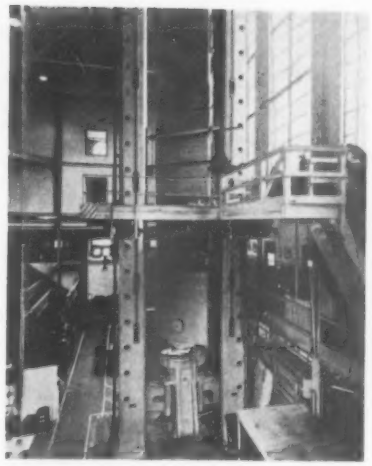


Fig. 3 Six-foot wide specimen ready for test in 3,000,000-lb machine

erally started in the strake of rimmed steel and, by changing the position of this strake, the length of the crack introduced to the arrester system could be controlled. The width of T steel was varied so that the arresting effect of various widths of this tough material could be compared and semikilled steel was used where needed to fill out the total specimen width. After a test, the fractured portion of the specimen was removed or repaired to provide another test from the same insert whenever possible. Typical 2-ft and 6-ft wide welded specimens are shown in Fig. 2.

Description of Tests

The details of the testing procedure and instrumentation have been described previously[1] but are briefly summarized for convenience. To study the feasibility of arresting brittle fractures, a dependable method of initiating and propagating a brittle crack was required. The early development work on this program and on a closely allied program which is concerned with the mechanics of the propagation of brittle fractures resulted in the adoption of a notch-wedge-impact method similar to the SOD method[2] for crack initiation. In the method adopted, a gas-operated piston device is used to drive a cold chisel into a $1^1/_8$-in. deep saw-cut notch (4-blade wide hacksaw cut terminated with a jeweler's saw-cut) at the edge of the specimen. A nominal impact of 1200 ft-lb is used for the initiation of the brittle cracks in all of the tests described. The 2-ft wide specimens are tested in a 600,000-lb screw-type testing machine and the 6-ft wide specimens in a 3,000,000-lb hydraulic testing machine.

The specimens tested in the initial stages of this program had little or no instrumentation. As the program progressed, it became evident that instrumentation of the specimens to measure crack speed and strain history at selected locations would be desirable and perhaps essential for the eventual interpretation of the results. Also, data of this nature would permit correlation with the results from the related program on brittle fracture propagation. Crack speed on the surface of the specimen is obtained from a series of suitably spaced SR-4 Type A-9 strain gages (6-in. gage length, single wire) which, when broken by the propagating crack, interrupt an electrical circuit. From the distance between detectors and the time interval between interruptions of the circuit, the average crack speed is computed. The strain history at various locations is obtained from the response of SR-4 Type A-7 strain gages ($^1/_4$-in. gage length). The signals from the strain

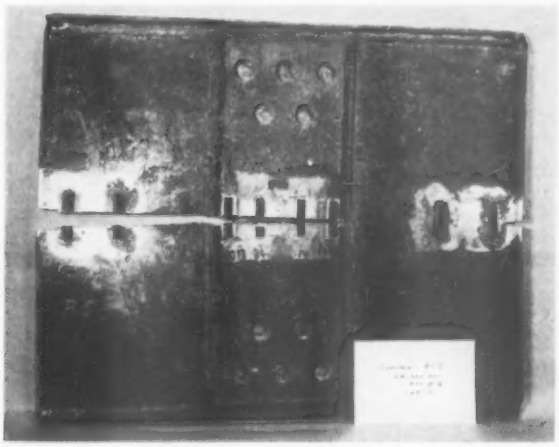


Fig. 4 Fracture path in 2-ft wide arrester specimen with fillet-welded doubler plate

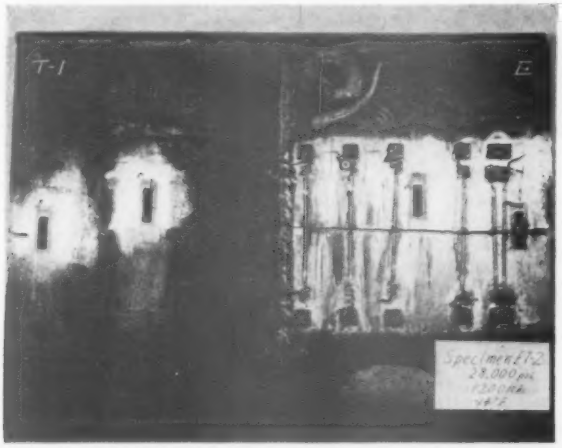


Fig. 5 Fracture path in 2-ft wide arrester specimen with butt-welded strake of *T* steel

arrester detail in the large riveted specimens was the same as a design used for ships in service. The large riveted arresters were fabricated by a qualified shipbuilder to insure that the laboratory specimens were typical of actual practice. For comparative purposes in the test program, a few specimens were fabricated without a slot beneath the doubler.

The first type of 2-ft wide welded arrester specimen investigated was similar in makeup to the riveted doubler-type arrester and consisted of a slotted rimmed-steel insert plate with a single doubler plate of A-285 steel welded over the slot. Subsequently, both sizes of welded arrester specimens were composed of various widths of rimmed (steel E or Z), T, and in some cases a semikilled steel (designated as Steel X) which were butt-welded together in a single plane with E12015 electrodes to provide the total desired width of specimen. The brittle crack was gen-

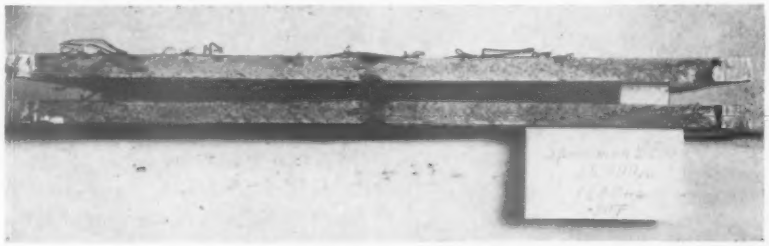
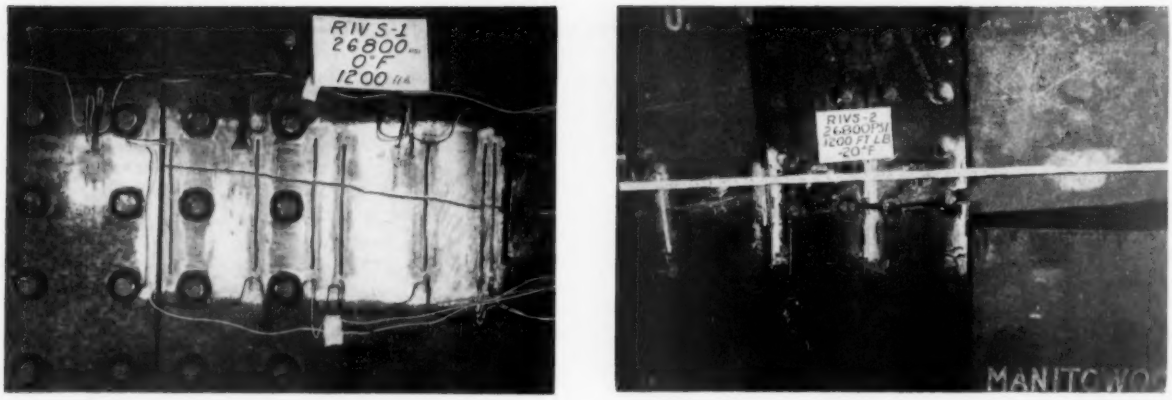


Fig. 6 Fracture surface across 2-ft wide arrester specimen with tough butt weld joining two plates of rimmed steel



a b

Fig. 7 Tests of 6-ft wide riveted arrester specimen with oxygen-cut slot

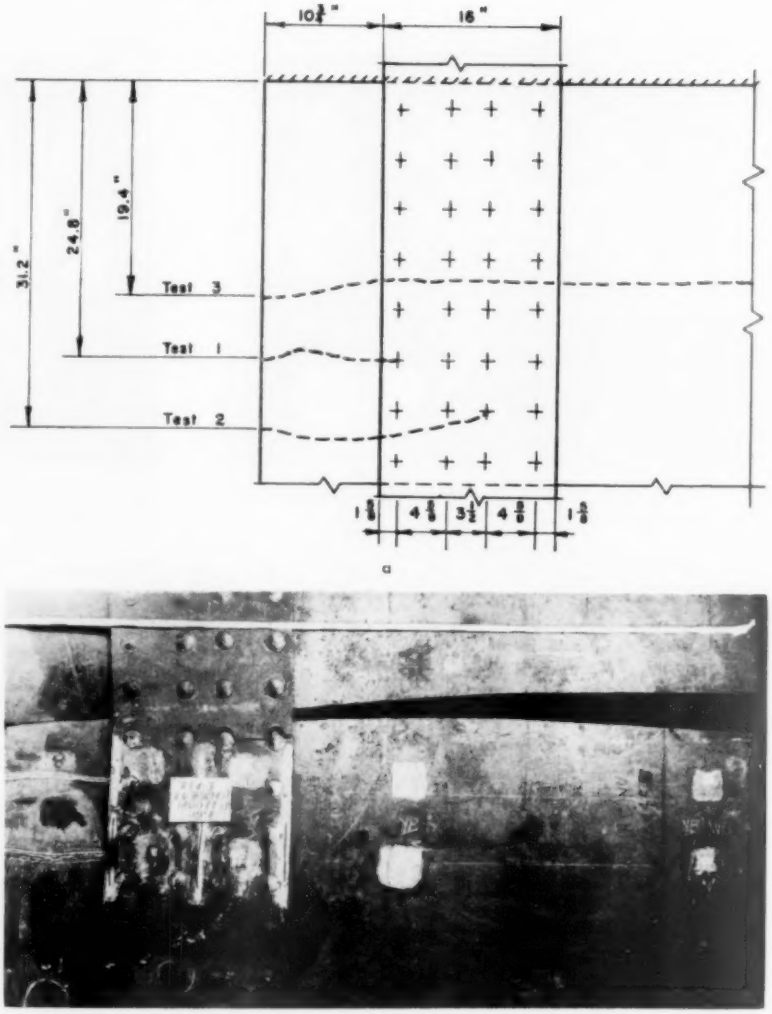
(a) Fracture path with crack initiated at edge near doubler.
(b) Fracture path with crack initiated at edge far from doubler.

gages and detectors are fed into cathode-ray oscilloscope equipment and recorded photographically with 35-mm strip-film cameras. For time intervals of 10 msec or less the strip-film camera is used as a single-frame camera to record the strain gage response as the trace moves once across the oscilloscope face at a predetermined sweep time. For times of several hundred milliseconds, the gage response is recorded on moving film. A detailed description of the sensing devices, recording devices, input circuits, triggering method, calibration procedure, stability, and data reduction process is presented in a previous paper.[1]

The specimen is cooled with crushed dry ice which is placed in containers hung on each side of the plate. In this manner, the specimens can be cooled to a temperature of approximately −20° F in about one and one-half hours.

Prior to the test the strain distribution in the specimen is checked at room temperature by applying the test load to the specimen at least once. After all instrumentation is checked, the specimen is cooled; the test load is applied; and the fracture is initiated by the notch-wedge-impact method. A 6-ft wide specimen ready for test is shown in Fig. 3.

In early tests on two foot wide specimens it was found that brittle fractures initiated by the notch-wedge-impact method consistently propagated completely across plain plate specimens of rimmed Steel E at an average stress of 15,000 psi, a temperature of 0° F, and a lateral impact of 1200 ft-lb. In general, the crack-arrester specimens are tested at higher stresses, somewhat lower temperatures, and the same lateral impact; this provides ample assurance of initiation and propagation of the brittle cracks in the starter material



a

b

Fig. 8 Fracture paths in tests of 6-ft wide riveted crack arrester specimen without oxygen-cut slot

(a) Notch location and fracture path for three successive tests of same insert.
(b) Path resulting from third test of specimen.

and subjects the arresting device to stress and temperature conditions which are relatively severe when compared to service conditions.

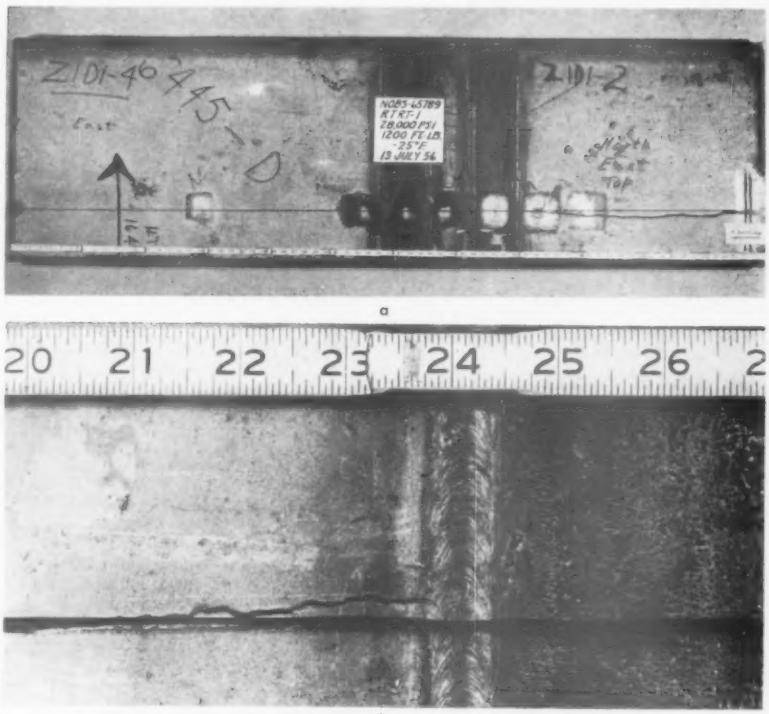
Test Results for 2-Ft Wide Specimens

The first type of welded crack-arrester specimen to be tested consisted of a doubler plate of A-285 steel plug and fillet welded over the slot in the main insert plate of rimmed Steel E. This arrangement was similar to a riveted doubler-plate detail used under service conditions.

Before welding the doubler plate to the main insert plate of one of these doubler-type specimens, SR-4 Type A-1 strain gages were mounted in a longitudinal direction $1^1/_2$ in. from each edge of the specimen ($^1/_2$ in. beyond the end of each notch). After the doubler had been welded to the insert plate, these gages near the edges of the plate indicated compressive residual strains as high as 1100 microinches per inch (μ in./in.). Thus, the fabrication of these specimens created approximately yield point compression at the base of the notch and a compressive strain field over the region ahead of the notch.

Whereas an applied tensile stress of about 15,000 psi was sufficient for the complete fracture of plain plate specimens of Steel E, an applied stress of over 22,000 psi was required for the initiation and propagation of brittle fractures in tests of the welded doubler-type specimens. Apparently, until offset by the application of a sufficiently large tensile stress, the aforementioned residual strain pattern hindered the initiation and propagation of a brittle crack in the specimens. A typical fracture of one of these doubler-type specimens is shown in Fig. 4. The brittle fracture propagated across the main plate to the oxygen-cut slot; also, it propagated through the connecting fillet weld and almost entirely across the attached doubler plate.

Because a slotted main plate and doubler plate combination would not be desirable in ships, particularly in tankers, only a few specimens of this type were tested. The program was then directed toward a study of specimens where the rimmed and tough steel were butt welded together in the same plane. The crack-arresting behavior of such a combination was studied in a preliminary fashion by butt welding 12-in. wide strakes of rimmed (E) and tough (T) steel together. SR-4 Type A-1 strain gages were mounted longitudinally $1^1/_2$ in. from the specimen edges before the two plates were butt welded together. After the fabrication of the specimen had been completed, compressive residual strains of less than 200 μ in./in. were present at these



a

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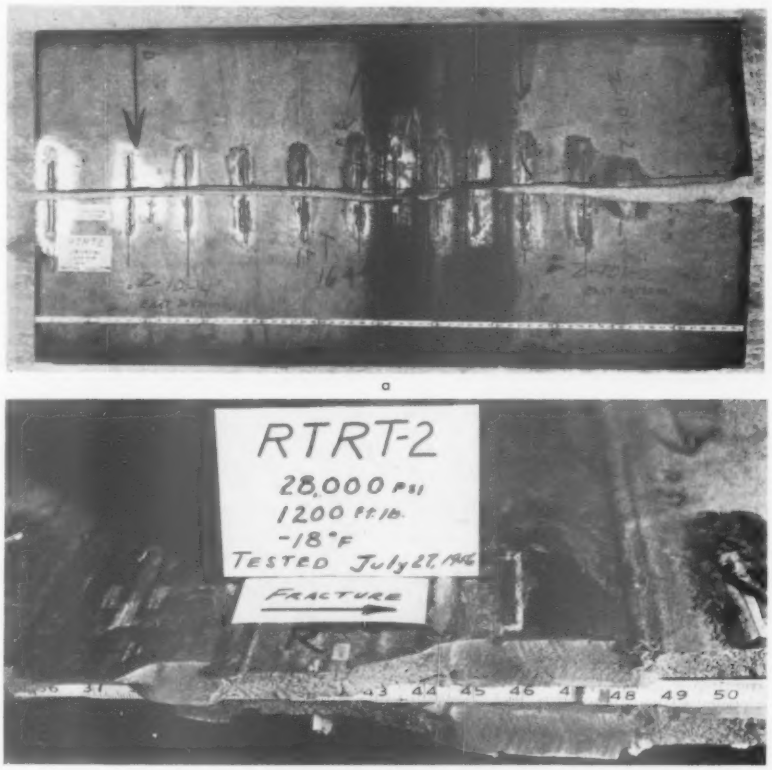
Fig. 9 Arrest of 2-ft long crack by 4-in. wide strake of *T* steel

(a) View of partially fractured insert.
(b) Surface of specimen around end of arrested crack.



a

b

Fig. 10 Propagation of 3-ft long crack across specimen containing two 4-in. wide strakes of *T* steel

(a) Fracture path across specimen.
(b) Fractured surfaces of *T* steel strakes and adjacent rimmed steel.

locations as compared with residual strains of about 1100 μ in./in. for the doubler-type specimens at the same locations. At an average stress of 17,000 psi and a temperature of +16° F, a brittle crack was propagated across the 12-in. width of rimmed steel but was not evident on the surface of the specimen across or beyond the butt weld. Increasing the nominal test stress to 28,000 psi in another test resulted, as shown in Fig. 5, in a slight reduction of thickness through the butt weld indicating the presence of a submerged crack (a crack which has propagated a short distance within the plate but has not emerged to the surface).

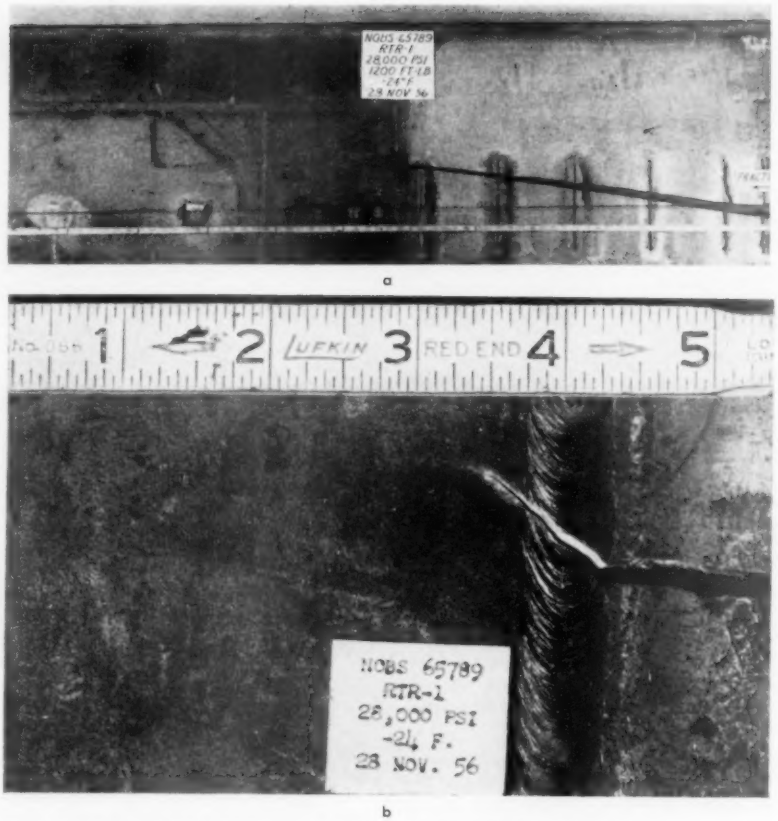
One specimen, composed of two 12-in. widths of rimmed steel E butt welded together with E12015 electrodes, was tested at 25,000 psi and +30° F. With the exception of part of the butt weld, this specimen fractured completely in a brittle manner as shown in Fig. 6. Thus the tough weld alone was not sufficient to arrest the propagating crack. Measurements of average crack speed showed a value of approximately 3000 fps as the fracture approached the butt weld and less than 700 fps as the crack crossed the weld. No crack speed information was obtained in the material beyond the butt weld.

Test Results for 6-Ft Wide Specimens

A few tests were conducted on riveted crack-arrester specimens with two different geometries, with and without a longitudinal slot in the main plate beneath the doubler. However, the major emphasis was on welded arrester specimens containing various combinations of starter and arrester materials. For uniformity and comparative purposes similar values of average net-section stress and test temperature were adopted for these tests. It was felt that the nominal stress should be high, but not high enough to produce gross plastic strain in the specimen, and the testing temperature should be low, but not excessively lower than service temperatures. On the foregoing basis, tests were generally conducted at an average stress of approximately 27,000 psi and a temperature of about −20° F.

One of the variables in the tests of this program was the length of brittle crack developed (width of starter material) before an arresting device was encountered. In the riveted arrester specimens, the crack propagated either approximately one foot or approximately four feet before encountering the region of the plate containing the doubler plate. In the various welded arrester specimens, the brittle crack propagated 1, 2, 3 or 4 ft before meeting a strake of tough material.

Crack detectors were placed on several of the riveted and welded arrester specimens in order that the speed of crack propagation in these specimens could be measured and compared with the speeds obtained in the tests of plain plate rimmed steel specimens. In general, the crack speeds in the starter strips of the arrester specimens were similar to the speeds obtained in the plain plate tests (primarily in the range of 3000 to 4000 fps) and were attained within the first 12 in. of travel from the notch. There appeared to be no increase of crack speed as the fracture progressed across the plate.



a

b

Fig. 11 Arrest of 3-ft long crack by 12-in. wide strake of T steel

(a) View of insert showing extent of propagation.
(b) Penetration of arrested crack into T steel.

Riveted Arrester Specimens

In the riveted specimens, the arresting device consisted of a 16-in. wide by $^3/_4$-in. thick doubler plate riveted to one side of the main insert plate with four vertical lines of countersunk pan head rivets. In one case, the insert plate contained a longitudinal slot centered beneath the doubler plate and in the other case it did not. While only the slotted specimen is typical of a type of arrester in general use, it was felt that similar tests of an unslotted specimen would provide an opportunity to compare the effectiveness of the two details.

Two tests were made on a riveted doubler specimen in which an oxygen-cut slot had been placed in the insert plate beneath the doubler. In one case the brittle crack was initiated from a notch at the edge of the specimen near the doubler and in the other case from a notch at the edge of the specimen farthest from the doubler. The notches were in line with a horizontal row of rivets. In the first case, the crack traveled slightly upward so as to pass between the horizontal rivet rows and extend to the oxygen-cut slot in the main plate, Fig. 7 (*a*). No fracture was apparent in the doubler plate.

The partial fracture of the specimen in the test just described was rewelded. In the second test on the specimen the crack, initiated from a notch at the opposite edge of the specimen, propagated across the main plate to the oxygen-cut slot. In addition, the doubler plate fractured across two lines of rivets as shown in Fig. 7 (*b*). From this test, it seems that an abrupt discontinuity such as is provided by an oxygen-cut slot is a satisfactory form of crack-arresting device, provided the redistribution of stress is not too great. In addition, it appears that a rivet hole also possesses some degree of arrest

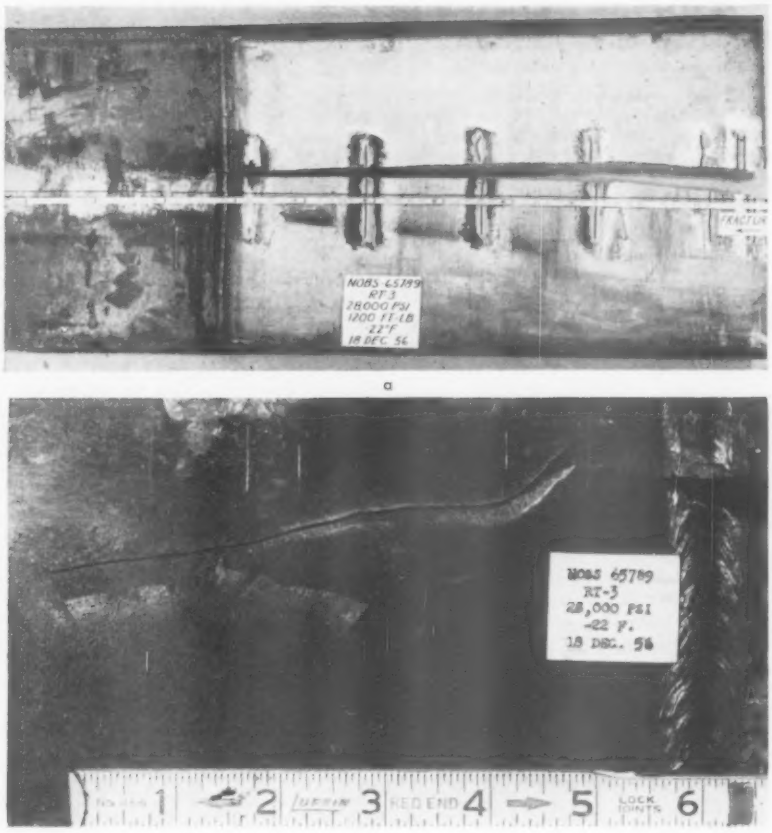


Fig. 12 Arrest of 4-ft long crack by 24-in. wide strake of *T* steel

(a) View of insert showing extent of propagation.
(b) Penetration of arrested crack into *T* steel.

ability; however, propagating brittle cracks are not necessarily attracted to the closest rivet holes and may, in fact, pass between them.

The riveted-arrester specimen without the longitudinal oxygen-cut slot was tested three times with the crack initiated from the edge near the doubler plate. Each attempt to fracture the specimen was made from a different location of the notch as shown in Fig. 8 (*a*). After each test, the fractured portion of the specimen was gouged out and the specimen rewelded for the next test. As can be seen in the figure, the first test was made with the crack initiated from a notch in line with one of the horizontal rows of rivets which connected the doubler and the insert plate. In this test the crack propagated to the rivet hole in the first vertical line. In the second test the crack was initiated from a notch located midway between two horizontal rows of rivets and in this case the crack propagated slightly upward to a rivet hole in the third vertical line. The third test on this specimen was made with the notch located so as to provide what seemed to be the greatest probability for uninterrupted crack propagation; in this test the notch was located just slightly above a horizontal row of rivets. The crack propagated completely across the main plate of the specimen passing approximately midway between two horizontal rows of rivets in the region where the doubler plate was connected. In addition, a crack was initiated and propagated from the far edge of the doubler back to the second vertical line of rivets, as can be seen in Fig. 8 (*b*). This third test indicated that it is possible to propagate a brittle crack across an unslotted riveted arrester. However, it is believed that such a failure would have been less likely if a staggered rivet pattern had been used.

In all of the riveted-arrester tests, the fracture surfaces of the rimmed steel had a brittle appearance and little reduction of area—very similar to the fracture surfaces of the plain plate rimmed-steel specimens being tested in the propagation program.[1] Fractures in both main plate and doubler exhibited this brittle behavior.

Welded-Arrester Specimens

In the welded specimens, 4-, 12-, 24- and 36-in. wide strakes of tough material (steel T) and E12015 electrodes were used in the fabrication of the various specimens to provide an arresting device. These arresting strips were used in combination with 1 to 4 ft widths of starter material (rimmed steel E or Z) in the different test specimens.

In the laboratory tests conducted on various 6-ft wide welded crack-arrester specimens, the following general results have been observed.

(*a*) An E12015 butt weld alone (i.e., not in combination with a strake of T steel) did not stop a brittle crack that had propagated across a 12-in. starter width of rimmed steel.

(*b*) A 4-in. wide strake of T steel stopped the propagation of brittle cracks which had developed lengths of 1 or 2 ft. Shown in Fig. 9 (*a*) is a specimen in which a crack propagated 2 ft and was then arrested by 4 in. of T steel. On the surface there is no indication of crack penetration in or beyond the butt weld, see Fig. 9 (*b*).

(*c*) During a period of about 10 sec, the crack in a specimen with a 3-ft long starter strip propagated completely across a specimen containing two 4-in. wide strakes of T steel which were 4 in. apart. This fractured specimen is shown in Fig. 10 (*a*). In Fig. 10 (*b*) can be seen the inclined fracture surface in both strips of T steel and the typical chevron-marked surface in the rimmed steel. Redistribution of the applied load created slight inelastic buckling at the edge of the specimen.

(*d*) In a specimen with a 3-ft long starter strip and a 12-in. wide strake of T steel, the crack only penetrated approximately 1 in. into the tough steel, see Fig. 11 (*a*). A view of the region in which the crack was arrested is shown in Fig. 11 (*b*). Extreme buckling occurred at the far side of this specimen.

(*e*) The brittle crack in a specimen with a 4-ft starter strip penetrated about 6 in. into and was arrested by a 24-in. wide strake of T steel. This fractured specimen is shown in Fig. 12 (*a*) and a closer view of the region of the T steel in which the crack was arrested is shown in Fig. 12 (*b*). Extreme buckling occurred on the far side in this specimen.

In all of the tests of welded-arrester specimens, the fracture surface of the rimmed and the semikilled steel had a brittle appearance and little reduction of area. However, where a brittle crack was propagated across or into a strake of T steel, the fracture surface in the tough steel was always on a 45-deg plane.

The final load for partly fractured specimens was approximately the same as the initial value for tests in which only a 12-in. long crack was developed. However, the final load, which is ec-

centric because of the crack, was approximately 90, 60 and 20% of the initial load for 24-, 36- and 48-in. long cracks. Although the loss of load on the specimen does not take place until some time after the brittle crack has propagated to the weld and strake of arrester material, the eccentric loading which follows creates severe bending and extremely high strains in the region at the end of the crack. Bending and redistribution of the applied load may cause buckling at the far edge of the specimen and thus affect further the conditions at the end of the propagated crack. The redistribution of load and the occurrence of buckling at the edge of the specimen undoubtedly have a considerable influence on the behavior of the arrester material. The effect of these conditions on the development and magnitude of strain has not been determined but is under study at this time.

In tests of 6-ft wide plain plates, the entire fracture process occurs in 1 to 2 msec. In most arrester tests, the time for the crack to propagate to the arresting device is less than 1 msec. During this interval, the strain gages across the remaining section (at least 6 in. ahead of the advancing crack) show little response for a period of a few milliseconds and then indicate a redistribution of stress. Shortly thereafter, for the few specimens where the records obtained are sufficiently long and dependable, the buckling at the far side of the specimen, if it occurs, becomes evident. In those specimens where the records were taken for a longer period of time, there was little change in the strain after approximately 100 msec; that is, the strain readings at a time of 100 msec were in good agreement with those measured about 10 sec later.

This program is still in progress. However, an attempt has been made in this paper to describe briefly the work and some of the observations to date. As indicated by the tests which have been described in this paper, strakes of tough steel butt welded to a less ductile material have arrested propagating brittle cracks under certain conditions. It is hoped that further study will help to provide an explanation of the mechanism of brittle fracture arrest, provide a means of evaluating the crack-arresting capability of various materials and eventually make it possible to formulate a dependable basis for the selection of welded crack arresters.

Acknowledgments

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The project is under the general direction of N. M. Newmark, Professor and Head of the Civil Engineering Department. V. J. McDonald, Research Assistant Professor of Civil Engineering, is in charge of instrumentation. The authors acknowledge the help of K. Hayashi and T. J. Hall, formerly Research Assistants, and J. N. Chopy, W. H. Walker and J. N. Kirk, presently Research Assistants, who assisted in the laboratory work.

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The members of the Crack Arrestor Advisory Committee of the Ship Structure Subcommittee have acted in an advisory capacity in the planning of this program.

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EFFECT OF METALLURGICAL VARIABLES ON TRANSITION BEHAVIOR IN CHARPY SLOW-BEND AND IMPACT TESTS

Three sub-critical heat treatments involving the phenomenon of quench aging, and variations in composition by the controlled addition of carbon and manganese as alloying elements, are the metallurgical variables selected for this study

BY C. E. HARTBOWER

ABSTRACT. V-notch Charpy slow-bend and impact tests have been conducted over a range of temperature to evaluate transition behavior in (1) three commercial structural steels subjected to sub-critical heat treatment, and (2) a number of laboratory heats containing controlled amounts of carbon and manganese. Particular attention was given to the selection of performance criteria that could be applied to both slow-bend and impact tests.

Comparisons between transition behavior in slow bend and impact revealed a complex interplay of velocity effect, and quench and strain aging. An increased rate of loading resulted in a significant shifting of the transition curves toward higher temperature in the case of stabilized material (furnace cooled from 1200° F and aged 30 days at 70° F); whereas, in the case of quenched (quenched from 1200° F and aged one day at 70° F) and quench-aged (quenched from 1200° F and aged 30 days at 70° F) material, little or no shift occurred. The lack of velocity effect in the latter two conditions was attributed to strain aging in the duration of slow bending which displaced the slow-bend transition curves toward higher temperature and thereby virtually eliminated the velocity effect. Comparisons between the quenched and quench-aged conditions revealed an appreciable embrittlement in both slow bend and impact as the result of quench aging, irrespective of deoxidation practice.

The effects of carbon and manganese on impact transition behavior were found to be consistent with the published literature. In general, carbon lowered the maximum energy and widened the transition range; whereas, increasing manganese shifted the entire curve to lower temperature without particularly changing the shape of the curve. In slow bend, carbon produced the same general trend as in impact. Increasing manganese, on the other hand, caused a greater shift in the low temperature portion of the slow-bend energy-temperature transition curve rather than the simple displacement observed in impact. The fibrosity-temperature transition curve confirmed the generally detrimental effect of increasing carbon and beneficial effect of increasing manganese. With increasing manganese, the displacement of the transition curves toward lower temperature was greater in impact than in slow bend and, as a result, the displacement between the slow-bend and impact curves decreased somewhat.

Because of the changes in shape of the transition curves produced by composition, aging and rate-of-loading variables, the definition of transition temperature required special attention. Definitions based upon fracture appearance could be applied directly to both slow-bend and impact tests. Equivalent criteria and definitions based upon energy (work) for slow-bend and impact tests, on the other hand, were more complicated. In slow bend, transition temperature was defined as the highest temperature permitting sudden and complete fracture (crack propagation) at maximum load; and in impact, transition temperature was defined as the temperature corresponding to the impact-energy level producing deformations (lateral expansion) equal to those occurring in slow-bend Charpy bars tested at the transition temperature. Transition temperatures thus determined, resulted in the same general trends as determined from a consideration of displacements in the transition curves.

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The opinions or assertions contained herein are the private ones of the author and are not to be construed as official or reflecting the views of the Department of the Army.

Introduction

Objective

The objective of this investigation was to study the effects of certain metallurgical variables on transition behavior as observed in V-notched Charpy specimens tested in slow bend and impact. The metallurgical variables selected for study were (1) three sub-critical heat treatments involving the phenomenon of quench aging, and (2) variations in composition by the controlled addition of carbon and manganese as alloying elements.

Materials

The steels used in this investigation were three commercial structural steels representing the full range of commercial de-oxidation practice (rimmed, semi-killed and fully killed*), and a series of 12 laboratory heats of controlled carbon and manganese contents. Metallurgical and physical property data are listed in Table 1.

The three commercial materials, prior to sub-critical heat treatment, were normalized at 1650° F for $^1/_2$ hr in the form of bars 2 in. x 10 in. x plate thickness. Finish-machined Charpy specimens were solution heat treated at 1200° F for 6 hr in evacuated quartz tubes. Subsequent to the 1200° F solution anneal, each material received three aging treatments, viz., stabilizing (furnace cooled from 1200° F and aged 30 days at 70° F), quenching (brine quenched from 1200° F and aged one day at 70° F), or quench aging (brine quenched from 1200° F and aged 30 days at 70° F).

The 12 laboratory heats of carbon-manganese steel were prepared under the direction of O. O. Miller and T. N.

* The fully killed steel was the same heat used in fabrication of 4 nine-ton welded box girders tested in conjunction with a research program conducted at the National Bureau of Standards under the auspices of the Structural Steel Research Committee of the Welding Research Council (Reference—C. E. Hartbower and W. S. Pellini, "Mechanical and Material Variables Affecting the Correlation of Laboratory Tests with the Performance of Structures," The WELDING JOURNAL, Vol. 29(7), p. 348-s (July 1950); and the fully killed steel in the $1^1/_2$ in. thickness together with the semikilled and rimmed steels, were the same heats used in a previous investigation of the effects of cooling rate from high sub-critical temperatures on the development of strain and quench aging. See Ref. 7.

Table 1—Commercial Steels Subjected to Sub-critical Heat Treatment

Chemical analyses

Material	*C*	*Mn*	*Si*	*Al*	*Nitrogen Soluble (1:1 HCl)*	*Nitrogen Insoluble*
Fully killed 1 1/2-in. plate	0.20	0.58	0.21	0.04	0.006	nil
Semikilled 1-in. plate	0.23	0.54	0.12	0.01	0.005	nil
Rimmed 3/4-in. plate	0.19	0.35	0.01	0.01	0.007	0.003

Laboratory Heats of Carbon-Manganese Steel

Heat no.	*Carbon (%)*	*Manganese (%)*	*ASTM grain size*	*Pearlite (%)*
20701-G	0.04	0.43	6	4
19924-B	0.09	0.43	6–7	10
20704-K	0.15	0.49	7–8	18
20705-M	0.21	0.47	8	25
19927-E	0.45	0.43	1–3	60
20702-H	0.04	0.74	7	4
20415-S	0.11	0.78	8	15
19925-C	0.20	0.69	8	25
20703-J	0.04	0.98	7	4
20416-T	0.10	1.03	8	12
20412-F	0.20	0.92	7–8	25
20706-N	0.31	1.05	8	40

Armstrong at the Research & Development Division, International Nickel Co., Inc., New York, N. Y. These steels, containing carbon ranging from 0.04 to 0.45% and manganese from 0.43 to 1.05%, were prepared as laboratory heats, deoxidized with silicon and aluminum to similate commercial fine-grain practice, forged to 5/8-in. square bar stock, and normalized from 1700° F.

Test Method

V-notch Charpy impact data on the 12 steels of varied carbon and manganese content were obtained from the work of T. N. Armstrong and W. L. Warner.[1] In addition to recording the energy absorbed in impact testing, the fracture appearance of each specimen was observed and the percentage of fibrous (or crystalline) surface estimated. Lateral expansion was measured by means of a flat-anvil micrometer at the compression side of the test bar opposite the notch. When fracture was incomplete, a single deformation reading was taken; when the test specimen was completely fractured, each half of the specimen was measured and the maximum value used in plotting.[2]

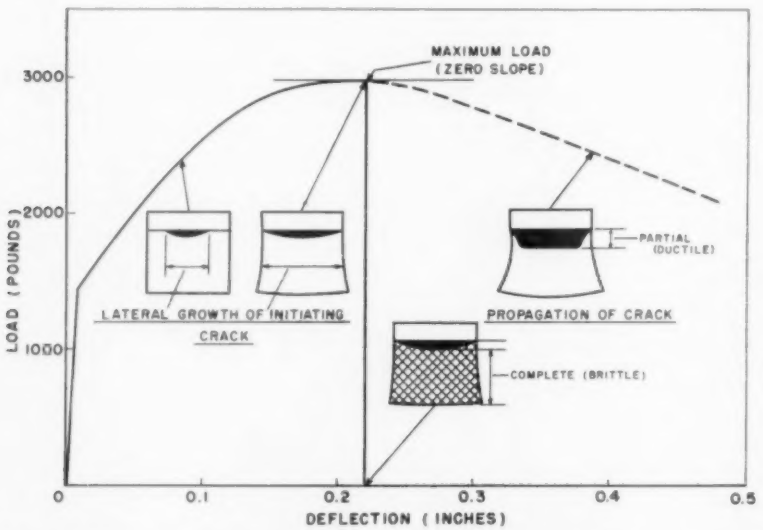

Fig. 1 Crack initiation and propagation in V-notch Charpy slow-bend testing

The depth of the initiating crack is essentially constant up to maximum load; whereas, the width increases laterally until at maximum load the crack extends to the sides of the test specimen. Beyond maximum load the crack propagates in the thickness direction with an attendant loss of load-carrying capacity. When the initiating crack propagates by continuous release of the elastic-stress field surrounding the crack (zero energy after maximum load), the fracture is considered to be brittle

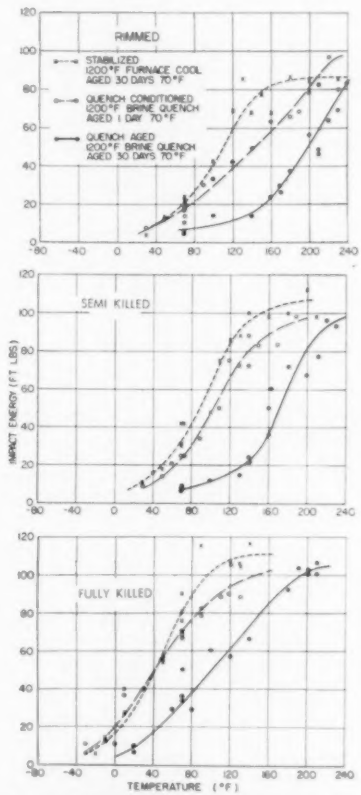

Fig. 2 Effect of aging on the energy-temperature relationship in impact

For purposes of slow-bend testing, the V-notch Charpy bar was supported by a fixture on the platen of a hydraulic testing machine and loaded by a ram fastened to the fixed head of the machine. Dimensions of the supporting fixture and the loading ram were made to conform with those specified for the anvil and the striking hammer in the standard Charpy impact test. The supporting fixture was contained in a tank so that the specimens could be tested while totally immersed in a liquid. The slow-bend specimens were loaded at a deflection rate of 0.01 in. per minute. The load-deflection diagram was automatically recorded by a microformer-type deflectometer actuated by the change in distance between the fixed head and the moving platen of the testing machine. The energy absorbed to a specific deflection or to fracture was calculated from planimeter readings of the area under the load-deflection curve.

The slow-bend test, in contradistinction to the impact test where adiabatic deformation occurs, was essentially isothermal in that the rate of loading was slow and the specimen was completely immersed in liquid.

Selection of Performance Criteria

In the last few years, it has become apparent to many investigators studying transition behavior in steel, that the choice of performance criterion may have a major influence on the conclusions drawn. For example, Rinebolt and Harris[3] observed that since the energy in the Charpy impact test goes into (1) bending, (2) initiation of the crack and (3) propagation of the crack, the various alloying elements in steel may have different effects on the energy required for these various events and, therefore, have different effects on the shapes of the transition curves. Rinebolt and Harris showed, in fact, that different shapes of transition curves exist, depending on the alloying elements present in the steel. Carbon, for example, was found to raise the transition temperature but lower the maximum energy and widen the transition range; thus, in using a definition of transition temperature based on 15 ft-lb, a high-carbon steel may be compared at 40% of its maximum energy, with a low-carbon steel at less than 10% of its maximum energy. It was observed that in view of this discrepancy, it is not surprising that the 15 ft-lb definition indicated the effects of carbon to be different from those indicated by other criteria and definitions investigated. With increasing manganese, the investigators observed that the entire curve was shifted to lower temperature without particularly changing the shape of the curve, i.e., the maximum energy, the lower end of the curve, and the width of the transition zone all stayed approximately the same. Because of the varied effect of the different alloying elements on the transition curve, the choice of performance criterion and the attending definition of transition temperature are essential considerations in evaluating the effect of metallurgical variables on brittle fracture.

In an earlier report to the American Society for Testing Materials, a particular definition of transition temperature was discussed for use in connection with V-notch Charpy slow-bend tests.[4] Transition temperature was defined as the highest temperature at which sudden and complete fracture occurred at maximum load, i.e., the temperature corresponding to zero energy after maximum load (Fig. 1). The definition of transition temperature was based on (1) an experimental observation by Raring that the start of crack propagation in the thickness direction of V-notch Charpy slow-bend bars coincides with the maximum in load as determined from the load-deflection diagram,[5] and (2) a suggestion by Orowan that one may differentiate between ductile and brittle fracture by noting the manner in which the initiating crack is propagated,[6] i.e., a brittle fracture crack is propagated by continuous release of the elastic stress field surrounding the crack; whereas, a ductile fracture crack requires plastic deformation work to extend the crack. Thus, with zero energy (work) after maximum load, the fracture may be considered to be brittle and the crack is referred to as "self propagating."

The criteria used in evaluating slow-bend performance were (1) lateral expansion (deformation), (2) fracture appearance (percent fibrosity) and (3) temperature. In particular, attention was focused on the deformation, fibrosity, and temperature attending catastrophic crack propagation (sudden and complete fracture of the test specimen at maximum load). The use of lateral expansion as a measure of the plastic-deformation work was based on earlier findings (see Ref. 2) which demonstrated that a direct proportionality exists between lateral expansion and energy absorbed in fracturing pearlitic-steel Charpy specimens.

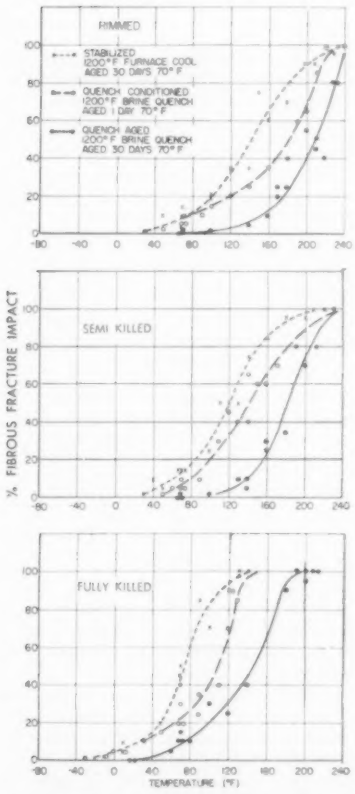
RIMMED
STABILIZED 1200°F FURNACE COOL AGED 30 DAYS 70°F
QUENCH CONDITIONED 1200°F BRINE QUENCH AGED 1 DAY 70°F
QUENCH AGED 1200°F BRINE QUENCH AGED 30 DAYS 70°F
SEMI KILLED
FULLY KILLED
% FIBROUS FRACTURE IMPACT
TEMPERATURE (°F)

Fig. 3 Effect of aging on the fibrosity-temperature relationship in impact

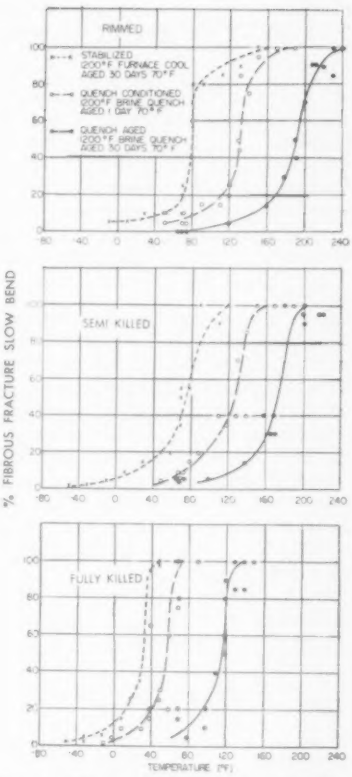
RIMMED
STABILIZED 1200°F FURNACE COOL AGED 30 DAYS 70°F
QUENCH CONDITIONED 1200°F BRINE QUENCH AGED 1 DAY 70°F
QUENCH AGED 1200°F BRINE QUENCH AGED 30 DAYS 70°F
SEMI KILLED
FULLY KILLED
% FIBROUS FRACTURE SLOW BEND
TEMPERATURE (°F)

Fig. 4 Effect of aging on the fibrosity-temperature relationship in slow bend

An appreciable amount of deformation was found to occur in V-notch Charpy slow-bend specimens tested at the highest temperature permitting sudden and complete fracture at maximum load. The lateral expansion occurring in such specimens was assumed to have occurred prior to crack propagation; based on this assumption, the deformation measured in such specimens reflected the plastic-deformation work done in bending and forming the initiating crack. Thus, it was possible to evaluate separately the crack-propagation and crack-initiation stages of the fracture process in slow bend.

In conventional notch-bar impact testing, results are usually expressed in terms of (1) energy absorbed in producing fracture, and (2) percent fibrosity (or crystallinity) in the fracture surface. In order to make quantitative comparisons between impact and slow rates of loading, it was considered necessary to apply the same criteria and definitions of transition temperature to both tests. Therefore, the criteria used in this investigation were restricted to the following:

Fracture appearance. Percent fibrosity can be estimated directly from the fracture surfaces in both slow-bend and impact test specimens. Two definitions of transition temperature were evaluated using this criterion, viz., (1) the

Table 2—Deformation Corresponding to the Onset of Brittle Fracture*

(Slow bend)

	—Rimmed—		—Semikilled—		—Fully killed—	
	in.	(%)	*in.*	(%)	*in.*	(%)
Stabilized	0.042	(10.6)	0.040	(10.2)	0.042	(10.6)
Quenched	0.030	(7.6)	0.030	(7.6)	0.032	(8.1)
Quench-aged	0.015	(3.8)	0.026	(6.6)	0.029	(7.4)

* Lateral expansion occurring in test specimens which fractured suddenly and completely at maximum load, i.e., with zero energy after maximum load.

highest temperature producing evidence of crystallinity in the fracture surface, and (2) the temperature corresponding to 90% crystallinity in the fracture surface. The latter was based on the fact that in slow-bend tests, the amount of fibrosity occurring at the highest temperature producing sudden and complete fracture at maximum load was found to be largely independent of composition and corresponded to approximately 90% crystallinity.

Work done (or energy absorbed). The calibrated impact-testing machine provides a direct measure of the energy absorbed in fracturing an impact specimen; the load-deflection diagram provides a measure of the work done in slow bending, and lateral expansion provides a measure of the plastic-deformation work done in fracturing the test specimen. Because of the changes in shape of the energy-temperature transition curves produced by composition variables, comparisons based on an arbitrarily selected energy level were rejected; instead, comparisons were based on the deformation level (measured as lateral expansion) corresponding to the amount of deformation attending brittle fracture in the slow-bend tests.

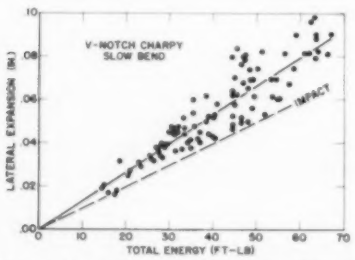

Fig. 5A Relation between Poisson effect and energy to fracture

The plot of lateral expansion versus total energy indicates a simple relationship that is largely independent of metallurgical variables. The dash curve represents the deformation-energy relationship for impact (from Ref. 2)

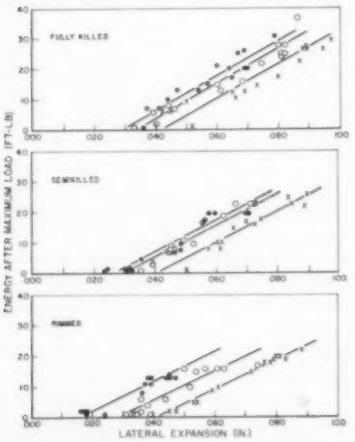

Fig. 5B Effect of aging on the energy-deformation relationship

(x) represents the stabilized condition, (o) the quenched (1-day) condition, and (•) the quench-aged (30-day) condition. Note that the relationship is no longer independent of metallurgical variables

TEST RESULTS

Effect of Aging on Transition Behavior

The over-all effect of sub-critical heat treatment on transition behavior at impact rates of loading is apparent from the energy-temperature transition curves. From an examination of Fig. 2, it may be seen that (a) an appreciable embrittlement occurred in all three steels as a result of the quench-aging (30-day) treatment, (b) the extent of the embrittlement was a function of deoxidation practice, with the fully killed steel least and the rimmed steel most embrittled and (c) at low energy levels, there was little difference between the transition curves for the stabilized and quenched (1-day) conditions. It should be noted

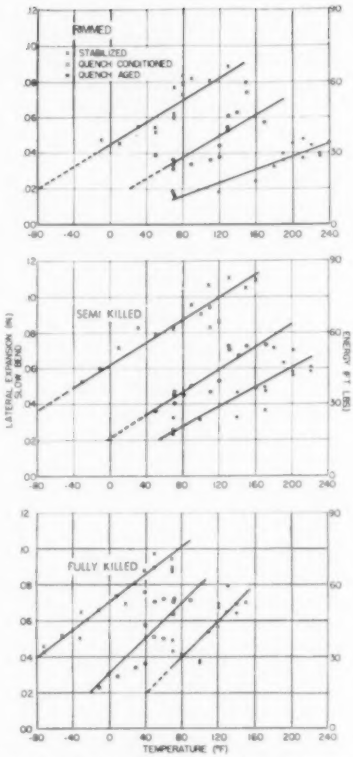

Fig. 6 Effect of aging on the deformation (energy)-temperature relationship in slow bend

in connection with the latter observation, that the upper portion of the transition-temperature curves for quenched and quench-aged materials may have been displaced as a result of accelerated aging occurring while the materials were exposed to the higher temperatures of test.

Similar observations are possible from the fibrosity-temperature impact transition curves (Fig. 3). Again, because elevated testing temperatures may have introduced accelerated aging, at-

Table 3—Transition Temperatures (°F)

		Rimmed		*Semikilled*		*Fully killed*	
	Criteria	*Slow*	*Impact*	*Slow*	*Impact*	*Slow*	*Impact*
Stabilized	90% cryst.*	+ 50	+ 80	+ 20	+ 60	−10	+30
	deform.†	− 10	+100	− 70	+ 80	−70	+30
Quenched	90% cryst.	+ 90	+ 80	+ 70	+ 80	+20	+30
	deform.	+ 50	+100	+ 20	+ 80	0	+20
Quench-aged	90% cryst.	+150	+160	+130	+140	+80	+80
	deform.	+ 70	+140	+ 70	+140	+60	+60

* Temperatures corresponding to 90% crystallinity in the fracture surfaces.

† Temperatures corresponding to (a) zero energy after maximum load in slow bend (see Table 2 and Fig. 6), and (b) energy levels producing equal amounts of deformation in impact; for example, it will be noted from Table 2 that the lateral expansion occurring in the quench-aged fully killed material at the highest temperature permitting brittle crack propagation in slow bend was 0.029 in. From the dashed curve of Fig. 5A, 0.029-in. lateral expansion is equivalent to 29 ft-lb impact. From Fig. 2, 29 ft-lb corresponds to approximately 60° F in impact and from Fig. 6, 0.029 in. corresponds to approximately 60° F in slow bend.

tention was focused on the lower portion of the curves. Note that, as in the case of the energy-temperature curves, there was little displacement between the lower portions of the stabilized and quenched (1-day) impact curves. A comparison between slow bend and impact is readily made on the basis of the fibrosity-temperature transition curves. From Figs. 3 and 4, note that slow bending resulted in a displacement between the stabilized and quenched (1-day) curves.

In addition to comparisons based on the displacement of curves, quantitative evaluations are expedited by the tabulation of transition temperatures. Two definitions were considered. Transition temperature based upon fracture appearance was defined as the temperature corresponding to 90% crystallinity in the fracture surface. This criterion and definition was particularly convenient in that it could be applied directly to both slow-bend and impact tests. The second definition of transition temperature was based upon the amount of deformation occurring in slow-bend specimens which fractured suddenly and completely at maximum load, i.e., the deformation corresponding to zero energy after maximum load (Fig. 5). These deformation values are listed in Table 2 and the slow-bend transition temperatures corresponding to these values, as determined from Fig. 6, are presented in Table 3. Temperatures producing equal amounts of deformation in slow bend and impact were determined on the basis of the direct proportionality that exists between lateral expansion and energy-to-fracture in pearlitic-steel Charpy bars. These are also presented in Table 3.

The effects of deflection rate and aging treatment as indicated by the transition temperatures listed in Table 3 are summarized in Table 4. The difference between slow bend and impact in the stabilized condition (upper portion of Table 4) is attributed to deformation rate per se; whereas, the relatively small or negligible differences indicated between slow bend and impact in the quenched (1-day) and quench-aged (30-day) conditions is attributed to strain aging occurring in the quenched (1-day) material while slow bending (strain aging shifted the slow-bend transition curves toward higher temperature and thereby reduced or eliminated the displacement between the slow-bend and impact transition curves). From the lower portion of Table 4, note that the magnitude of the increase in transition temperature of the quench-aged (30-day) over the quenched (1-day) condition was essentially constant irrespective of material or rate of loading; the difference (approximately 50° F) between the 1-day and 30-day conditions is at-

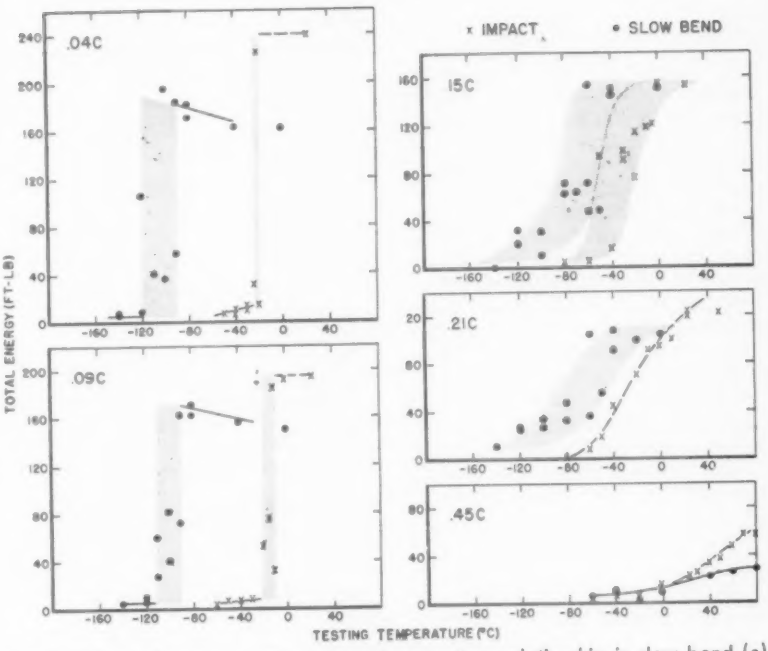

Fig. 7 Effect of carbon on the energy-temperature relationship in slow bend (•) and impact (x)

The steels shown contain essentially constant manganese (0.43-0.49%)

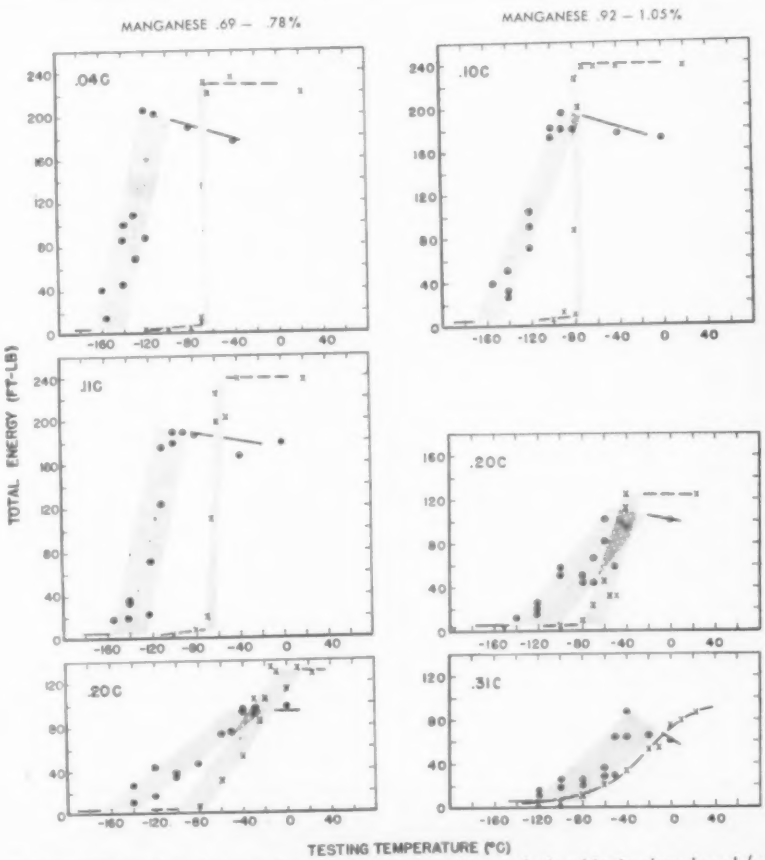

Fig. 8 Effect of carbon on the energy-temperature relationship in slow bend (•) and impact (x)

tributed to quench aging. The rise in transition temperature in the quenched (1-day) condition over the stabilized condition in slow bending is attributed to strain aging in the quenched material while slow bending (it was demonstrated in an earlier report[7] that a subcritical quench, conditions these materials for strain aging).

Note that the effects as determined on the basis of deformation and fracture appearance are similar with one notable exception, viz., the magnitude of the differences in transition temperature between slow-bend and impact rates of loading were generally much greater on the basis of the deformation criterion.

The Effect of C and Mn on Shape and Displacement of Transition Curves

Total energy as measured by planimeter from the slow-bend load-deflection diagrams was plotted against testing temperature and, for comparison, the transition data obtained in impact by Armstrong and Warner were replotted on the same coordinate system. Five heats, containing carbon ranging between 0.04 and 0.45 percent with essentially constant manganese (0.43 to 0.49 percent) are compared in Fig. 7. The data show that carbon had a marked effect on the shape of the transition curve and that the effect was similar in slow bend and impact. Note that as carbon (pearlite) was increased, the

Table 4—Increase in Transition Temperature (° F) with Increased Rate of Loading

(Impact vs. slow bend)
(See Table 3)

	Criteria	*Rimmed*	*Semikilled*	*Fully killed*
Stabilized	90% cryst.	30	40	40
	deform.	110	150	100
Quenched	90% cryst.	−10	10	10
	deform.	50	60	20
Quench-aged	90% cryst.	10	10	0
	deform.	70	70	0

Increase in transition temperature (° F) produced by aging treatments
(See Table 3)

		Rimmed		*Semikilled*		*Fully killed*	
	Criteria	*Slow*	*Impact*	*Slow*	*Impact*	*Slow*	*Impact*
Quenched vs. stabilized	90% cryst.	40	0	50	20	30	0
	deform.	60	0	90	0	70	−10
Quench-aged vs. quenched	90% cryst.	60	80	60	60	60	50
	deform.	20	40	50	60	60	40

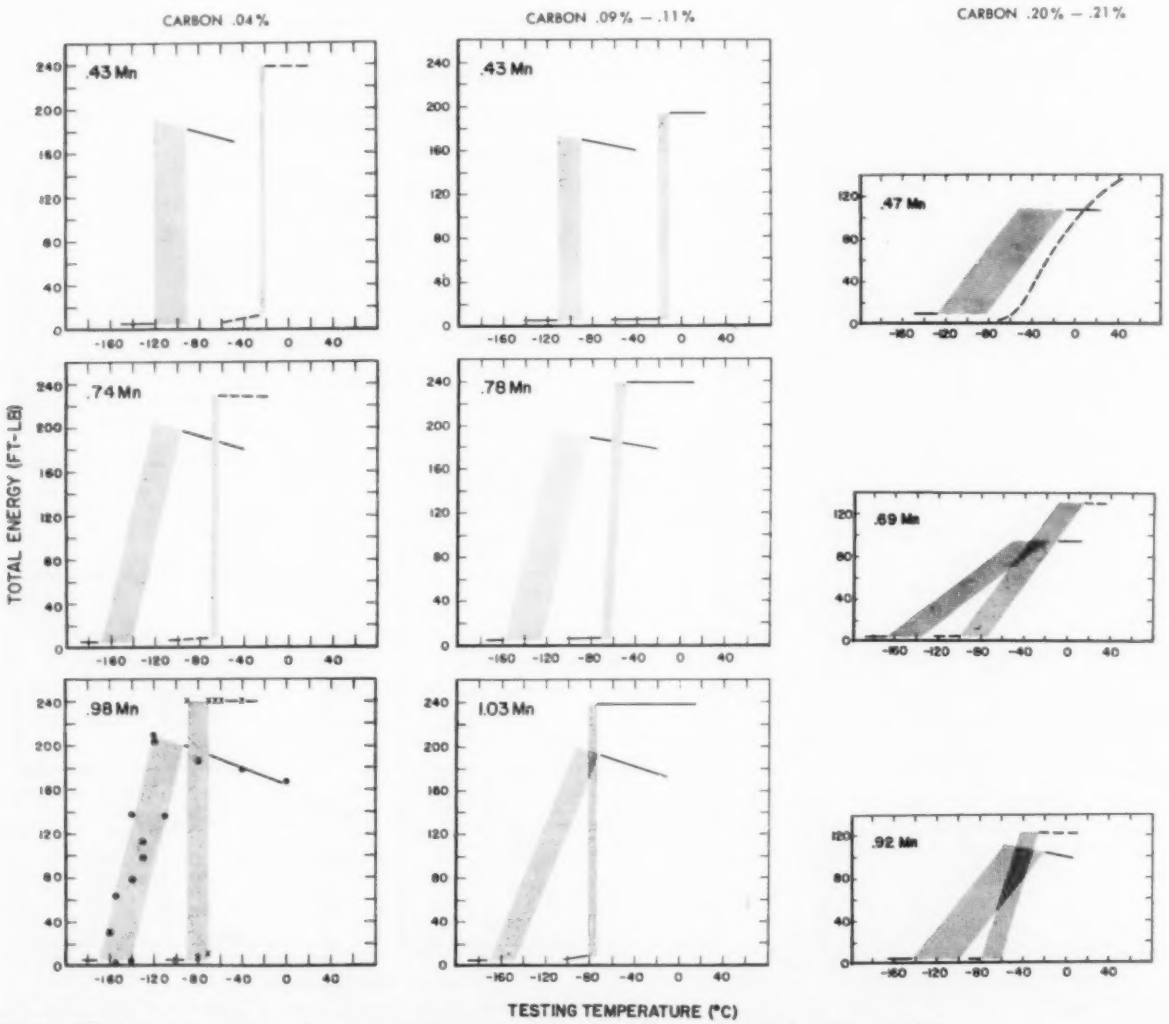

Fig. 9 Effect of manganese on the energy-temperature relationship in slow bend (•) and impact (x)

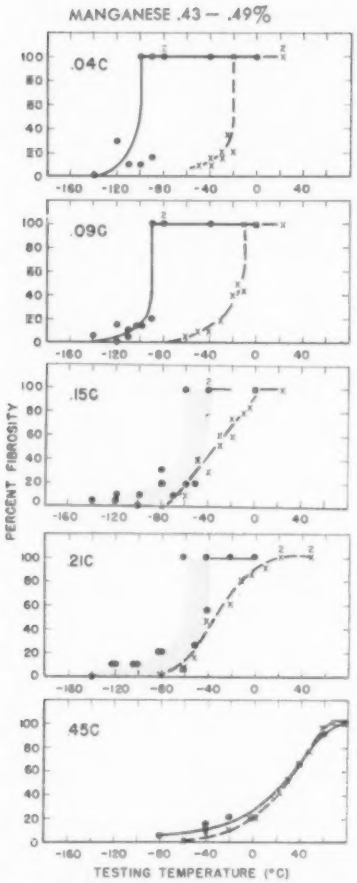

Fig. 10 Effect of carbon on the fibrosity-temperature relationship in slow bend (•) and impact (x)

maximum energy and slope of the curve was decreased, and that although the displacement between the slow bend and impact curves decreased with increasing carbon content, impact loading generally shifted the transition curve to higher temperature.

Two additional groups of laboratory heats containing varying amounts of carbon at progressively higher levels of manganese are presented in Fig. 8. The same general trends were observed at all three composition levels.

The transition curves for three series of laboratory heats containing varying amounts of manganese at three carbon levels are compared in Fig. 9. It should be noted in connection with these plots that, with one exception, these are regroupings of the transition curves presented in Figs. 7 and 8; the repeated curves are shown without plotted points. The curves as presented in Fig. 9 show that as manganese was increased at a given carbon level, the impact curve was shifted to lower temperature without an appreciable change in shape or maximum energy level; whereas, in slow bend the lower portion of the curve was shifted more than the upper portion.

The same heats, grouped as they were in Figs. 7, 8 and 9 according to carbon and manganese content, are presented in Figs. 10, 11 and 12 as fibrosity-temperature transition curves. The data as plotted in Fig. 10 show that the transition from ductile-to-brittle fracture appearance was raised by increasing carbon (pearlite) content, and that the trend was similar for both slow bend and impact rates of loading. Note that the extent of the difference in transition temperature between slow bend and impact decreased with increasing carbon content. The data as plotted in Fig. 11 show the same trends at higher manganese levels. The data as plotted in Fig. 12 show the effect of varied manganese content at three levels of carbon. Increasing manganese is shown to have produced a general displacement of the transition curve toward lower temperature; the effect, however, was greater in impact than in slow bend; as a result, with increasing manganese the displacement between the slow-bend and impact transition curves decreased somewhat.

Thus, carbon was found to both shift and change the shape of the transition curves. Manganese, on the other hand, shifted the curves in impact and both shifted and somewhat changed the shape of the curves in slow bend. The effect of increasing carbon in changing the shape of the transition curves consisted of a lowering of the maximum energy and a widening of the range of temperature over which the transition from ductile-to-brittle behavior occurred. With increasing carbon, the transition occurred at increasingly higher temperature; increasing manganese, on the other hand, generally lowered the transition.

From the conventional energy-temperature and fibrosity-temperature transition curves, it is evident that both the difference in deflection rate between slow bend and impact, and the metallurgical variables introduced by composition, affect the transition from ductile-to-brittle behavior. However, the curves do not differentiate between the various stages involved in the fracture process; i.e., the impact-energy and slow-bend-work determinations provide only an integration of the various stages of the fracture process, viz., resistance to bending, crack-initiation, and crack-propagation. Moreover, although general comparisons between transition curves often indicate similar overall trends regardless of the choice of performance criteria used, it is apparent that because of the changes in shape of the transition curves produced by various metallurgical variables, the conclusions drawn with respect to transition behavior may be dependent on the choice of performance criteria and in particular on the attendant definition of transition temperature.

Effect of C and Mn on Transition Temperature

The selection of transition temperature is necessary if the effects of carbon and manganese on transition behavior are to be quantitatively evaluated. Transition temperatures based on fracture-appearance criteria are considered first because they can be applied directly to both slow bend and impact. Table 5 columns (a_s) and (a_i) show the effect of carbon and manganese on the highest temperature at which crystallinity occurred in the fracture surfaces. Note that with increasing carbon, there was a general trend for crystallinity to occur at increasingly higher temperatures in both slow bend and impact. However, with increasing manganese,

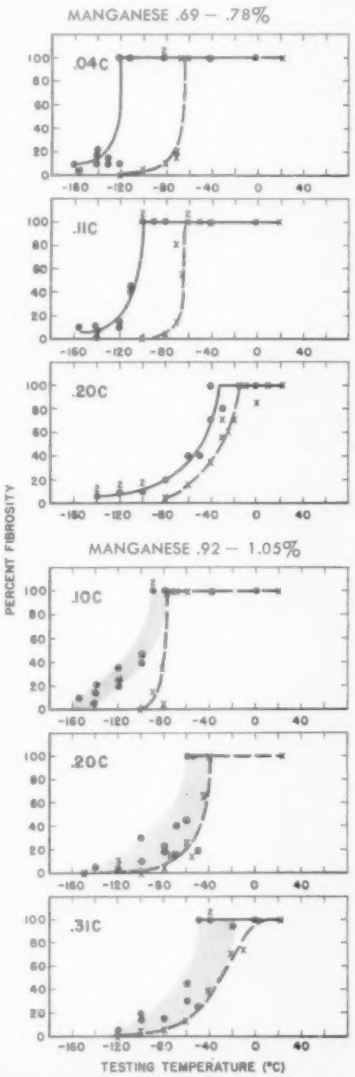

Fig. 11 Effect of carbon on the fibrosity-temperature relationship in slow bend (•) and impact (x)

little or no effect was observed in slow bend; whereas, in impact, increasing manganese resulted in a lowering of transition temperature. Another definition of transition temperature is based upon the lower portion of the fibrosity-temperature curves, viz., 90% crystallinity (Table 5, columns b_s and b_i). This definition is of interest because it was previously shown[4] that the amount of fibrosity attending the onset of brittle fracture in slow bend is largely independent of carbon and manganese contents (in the C-Mn steels investigated the amount of crystallinity occurring at the onset of brittle fracture fell within the range of 80–100 percent—arithmetical average, 90% crystallinity). Note that with increasing carbon content there was a general trend toward higher transition temperatures in both slow bend and impact; whereas, with increasing manganese content, the transition temperatures tended to be lowered.

Column (c_s) of Table 5 shows the effect of carbon and manganese on the highest temperature permitting sudden and complete fracture at maximum load (onset of brittle fracture in slow bending). With increasing carbon content, there was a general trend for the onset of brittle fracture to occur at increasingly higher temperature; whereas, with increasing manganese content, the onset of brittle fracture tended to occur at progressively lower temperature. Note that to all practical purposes, the transition temperatures in slow bend based upon 90% crystallinity were the same as determined on the basis of the self-propagating-crack criterion (compare columns b_s and c_s of Table 5). Column (c_i) presents the temperatures corresponding to impact-energy levels producing deformations equal to those occurring in slow-bend bars at the highest temperature permitting brittle-crack propagation. Note that with increasing carbon there was little or no change in transition temperature except for a marked rise in the case of the 0.45% steel; increasing manganese, on the other hand, resulted in a significant lowering of transition temperature.

Attention is invited to the similar behavior patterns indicated in columns (b_i) and (c_i). Moreover, certain general trends may be observed in Table 5 irrespective of transition-temperature definition or rate of loading. For example, at a given manganese level, increasing the carbon from 0.04 to 0.11% had no effect on transition temperature (likewise an increase in carbon from 0.15 to 0.20% produced no significant change).

Table 6 shows the effect of increased rate of loading on transition temperature. Based on the onset of crystallinity note that the difference between transition temperatures in slow bend and impact generally decreased with in-

Table 5—Transition Temperatures (° C)

	Slow bend			*Impact*		
	*Onset of cryst.** (a_s)	*90% cryst.* (b_s)	*Onset of brittle† fracture* (c_s)	*Onset of cryst.* (a_i)	*90% cryst.* (b_i)	*Onset of brittle‡ fracture* (c_i)
Carbon (%) (0.43–0.49%Mn)						
0.04	− 90	−110	− 90	−20	−40	−20
0.09	− 90	−110	−100	−10	−50	−20
0.15	− 50	− 80	− 60	− 5	−60	−30
0.21	− 40	− 80	− 60	+10	−60	−30
0.45	+ 60	− 40	− 20	+60	−20	+20
(0.69–0.78%Mn)						
0.04	−120	−140	−120	−70	−80	−60
0.11	−110	−130	−120	−65	−70	−60
0.20	− 30	−100	−100	0	−70	−60
(0.92–1.05%Mn)						
0.04	−110	−150	−140	−70	−90	−80
0.10	−100	−140	−140	−80	−90	−80
0.20	− 50	−100	−100	−40	−70	−60
0.31	− 20	− 80	− 80	0	−70	−50
Manganese(%) (0.04%C)						
0.43	− 90	−110	− 90	−20	−40	−20
0.74	−120	−140	−120	−70	−80	−60
0.98	−110	−150	−140	−70	−90	−80
(0.09–0.11%C)						
0.43	− 90	−110	−100	−10	−50	−20
0.78	−110	−130	−120	−65	−70	−60
1.03	−100	−140	−140	−80	−90	−80
(0.20–0.21%C)						
0.47	− 40	− 80	− 60	+10	−60	−30
0.69	− 30	−100	−100	0	−70	−60
0.92	− 50	−100	−100	−40	−70	−60

* Highest temperature producing crystallinity in the fracture surface.

† Highest temperature producing brittle crack propagation (zero energy after maximum load).

‡ Temperatures corresponding to impact energy levels producing deformations (lateral expansion) equal to those occurring in slow bend at the onset of brittle fracture (c_s).

Table 6—Increase in Transition Temperature with Increased Rate of Loading

(Impact vs. slow bend)
(See Table 5)

	Temperature (° C)		
	Onset of cryst.	*Onset of brittle fracture*	*90% cryst.*
Carbon (%) (0.43–0.49%Mn)			
0.04	70	70	70
0.09	80	80	60
0.15	45	30	20
0.21	50	30	20
0.45	0	40	20
(0.69–0.78%Mn)			
0.04	50	60	60
0.11	45	60	60
0.20	30	40	30
(0.92–1.05%Mn)			
0.04	40	60	60
0.10	20	60	50
0.20	10	40	30
0.31	20	30	10
Manganese (%) (0.04%C)			
0.43	70	70	70
0.74	50	60	60
0.98	40	60	60
(0.09–0.11%C)			
0.43	80	80	60
0.78	45	60	60
1.03	20	60	50
(0.20–0.21%C)			
0.47	50	30	20
0.69	30	40	30
0.92	10	40	30

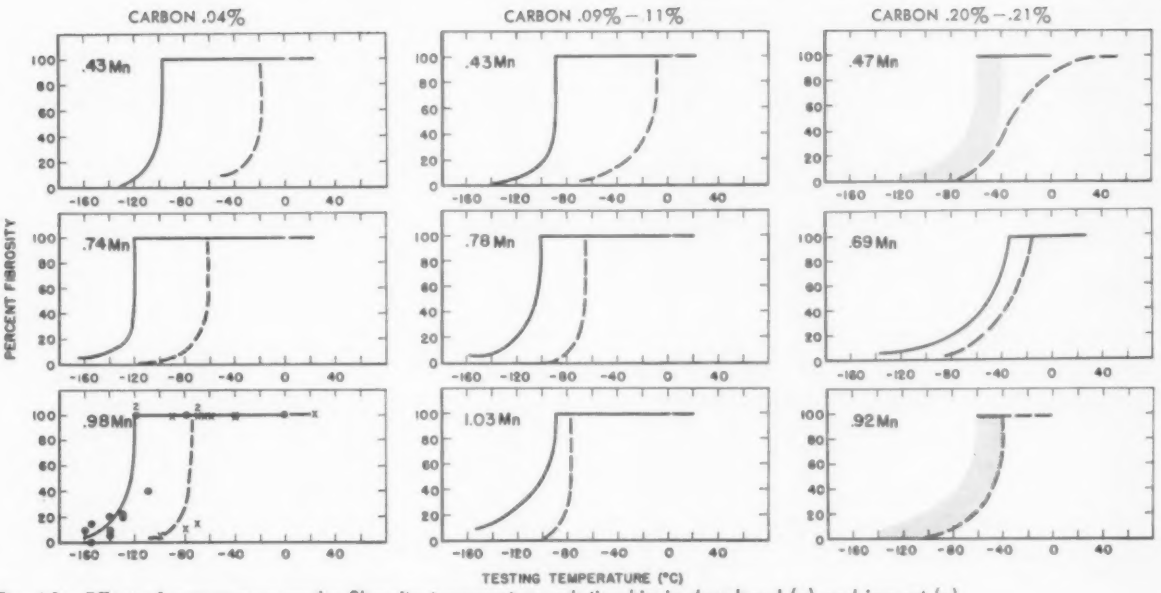

Fig. 12 Effect of manganese on the fibrosity-temperature relationship in slow bend (•) and impact (x)

creasing carbon and manganese contents. Transition temperatures based upon 90% crystallinity and the onset of brittle fracture also showed a generally decreasing velocity effect with increasing carbon, but showed little or no trend with increasing manganese content.

Summary Discussion of Results

Carbon both shifted and changed the shape of the transition curve and manganese shifted the curve in impact, and both shifted and somewhat changed the shape of the curve in slow bend. The effect of increasing carbon in changing the shape of the transition curve consisted of a lowering of the maximum energy and a widening of the range of temperature over which the transition from ductile-to-brittle behavior occurred. With increasing carbon, the transition occurred at increasingly higher temperature; manganese, on the other hand, generally lowered the transition.

Sub-critical heat treatments which conditioned the materials investigated for quench and strain aging resulted in a varied transition behavior which depended upon the rate of loading and the aging treatment. While there was no significant difference in the transition curves between the stabilized and quenched (1-day aged) conditions in impact, an appreciable difference between the two conditions occurred in slow bend. The difference between the stabilized and quenched (1-day) conditions in slow bend was attributed to strain aging occurring in the duration of slow bending. All three materials, irrespective of deoxidation practice, showed a marked displacement of the transition curves to higher temperature as the result of quench aging for 30 days at room temperature.

Transition curves obtained in impact were generally displaced toward higher temperature as compared to those obtained in slow bend. Three notable exceptions were observed: (1) as the carbon content was increased, the displacement between the slow-bend and impact transition curves decreased: (2) with increasing manganese content, the displacement between the slow-bend and impact fracture-appearance transition curves decreased as the result of manganese having a somewhat greater beneficial effect in impact than in slow bend; and (3) in the quenched (1-day aged) and quench-aged (30-day) conditions, the slow-bend and impact fracture-appearance transition curves coincided in the low-temperature range as a result of strain aging occurring in the duration of slow bending.

Comparisons based on (a) the relative displacements of transition curves and (b) changes in transition temperature, generally indicated similar over-all trends regardless of the performance criterion used. However, it is apparent from a consideration of the changes in shape of the transition curves produced by composition, aging, and rate-of-loading variables that only through careful attention to the physical significance of the definitions of transition temperature and the use of equivalent definitions in the slow-bend and impact tests, was it possible to develop consistent trends. The definitions of transition temperature in impact remain somewhat arbitrary in that their significance in terms of brittle fracture has not been determined. Studies are in progress to determine the significance of the various portions of the impact transition curve in terms of resistance to crack initiation and crack propagation. Although a technique is available for distinguishing between the crack-initiation and crack-propagation stages of fracture in the Charpy impact test,[8] there was insufficient material remaining in the heats under investigation for application of the technique.

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A NEW NODULAR CAST-IRON WELDING ROD FOR FOUNDRIES AND FABRICATORS

Data is presented to show that a nodular-iron welding rod of suitable chemistry under proper oxyacetylene welding technique can form a weld-metal-bead of a fully-nodular ferritic-iron structure

BY R. O. DAY, J. S. SNYDER, AND H. V. INSKEEP

Introduction

The increasing tonnage of nodular, or ductile, cast iron being produced and its widening field of useful application attests to the importance that industry places upon this material. Because of its interesting mechanical properties, nodular iron is proving a very valuable material to the foundry industry and to users of castings. While the bulk of this material will continue to be used for casting complete units, it also shows promise as a material from which cast components can be made for assembling by welding methods.

In some cases, nodular cast iron has mechanical properties approaching those of many grades of steel. Its tensile strength ranges from around 50,000 to 150,000 psi as cast. It has a yield strength from 40,000 to 120,000 psi with an elongation in 2 in. from 2% to 25%. As may be expected, its ductility declines with increases in tensile strength. As can also be expected, the as-cast condition produces higher strengths and lower ductility than do pieces that have been heat treated after casting.

Gray cast iron has its graphite in the form of random flakes that break up the continuity of the matrix. By way of contrast, free graphite in nodular iron is in the form of spheroids or nodules. In this form, the continuity of the matrix material is markedly increased. It is this difference that is chiefly responsible for the difference in mechanical properties of the two types of iron.

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Past Problems of Welding

The welding of nodular iron has been reported in the literature only a few times. Papers on the subject have been pessimistic. Opinions by individuals handling nodular iron have also been pessimistic regarding joining nodular iron with nodular-iron filler metal. Reports on tests using other filler metals have indicated much to be desired regarding tensile strength, freedom from fissures and color match. Apparently, nodular iron, as foundries now cast this material, could not be used as a filler material.

Table 1—Mechanical Properties

	Nodular iron	*Gray iron*
Ultimate strength, psi	133,500	46,500
Yield Point, psi	80,000	...
Elongation, % in 2 in.	9.5	...

This situation represented a challenge. Work was therefore undertaken to discover a method to make a nodular iron which could be used for filler metal. This paper presents the present status of this work. The results look very acceptable; and as shown here, a welding rod in the medium strength range has been developed. It yields a fully nodular deposit with a reasonable ductility using the oxyacetylene method of welding. Deposits made with this rod by means of the gas-shielded tungsten-arc method of welding are also nodular and of good quality.

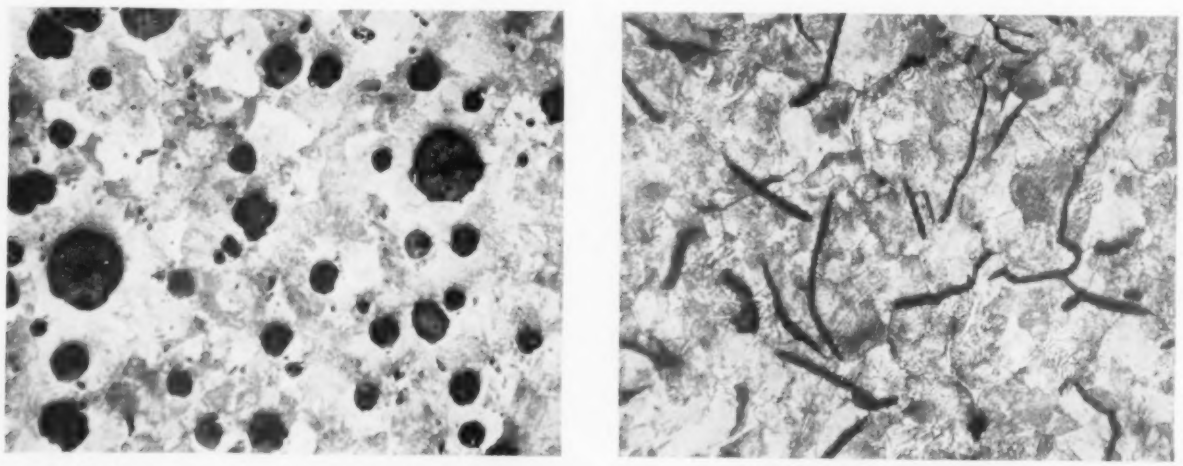


Fig. 1 Photomicrographs of two base materials in the as-cast condition are shown. Nodular iron is at left and gray iron, right. For information on mechanical properties, see Table 1

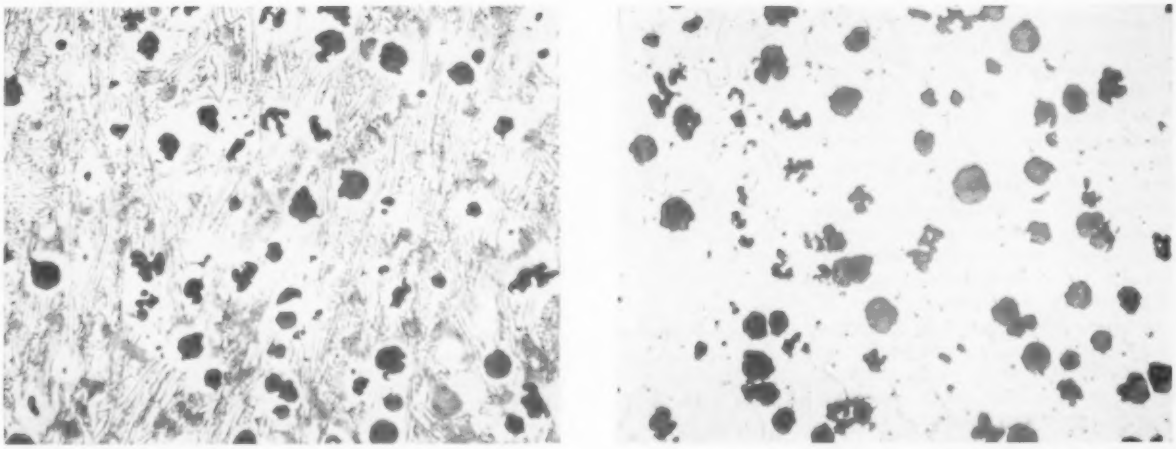


Fig. 2 These two structures were formed by gas tungsten-arc welding made with nodular-iron welding rod, before and after annealing at 1600° F. The as-welded structure (*left*) has a hardness of 35 to 45 Rockwell C, while the annealed structure averages 90 Rockwell B

Control Factors for Welding

Major controlling factors when welding cast iron are welding technique and the chemistry of the iron. Oxyacetylene welding techniques, which have been developed over the years, produce a very satisfactory weld in either gray or nodular cast iron. Improper techniques can very easily produce a hard and brittle material in the weld and in the immediately adjacent heat-affected zone. However, proper manipulation of the welding flame preheats the area surrounding the weld and allows heat to penetrate into the base material, preventing the formation of the hard and brittle material. This method of control appears to be easier in the welding of noduflar iron than in the case of gray iron. With respect to arc-welding techniques, the results of investigation now indicate that these techniques can be developed to produce an entirely satisfactory weld. Based on experimental data, annealed arc welds in nodular cast iron can present very favorable and useful mechanical properties.

As previously stated, chemistry of the iron is an important control factor in cast-iron welding. Cast iron containing a considerable amount of pearlite will produce a higher hardness in the heat-affected zone and at the weld junction than will the iron which is predominately ferritic. The alloy content of an alloy gray iron also has a considerable metallurgical effect after welding. This is mainly because most of the commonly used alloying elements are carbide formers and hardeners which increase the quench-hardening tendency of the iron. Much of the same can be said of the welding of nodular cast iron—namely, that a higher pearlite or alloy content will increase the hardness zones surrounding the weld. However, by using what might be called normal oxyacetylene welding techniques, there are not many irons (particularly in the nodular group) which cannot be satisfactorily welded.

Table 2—Mechanical Properties

	Gas tungsten-arc weld
Ultimate Strength, psi	58,000
Yield Point, psi	39,000
Elongation, % in 2 in.	7.5
Bend Elongation, % in 1 in.	15.0
Impact Resistance, ft-lb	24.5

Laboratory Test Procedure

When used with incorrect welding technique, gray-iron welding rods, regardless of chemistry, can produce a deposit that is harder than desired. Even with good chemistry and correct techniques, it is difficult to keep hardness at a desirable level. This is a serious defect when the weld area must be machined, because the hardness of the deposit is very frequently close to or above the maximum hardness for satisfactory machining. Although fully-ferritic iron rod may deposit largely ferritic weld metal with a reasonably satisfactory hardness, other mechanical properties including strength of the deposited metal may be unsatisfactory.

When welding nodular cast iron, the use of a suitable nodular-iron welding rod appears to create the most desirable combination. As a result, a nodular-cast-iron welding rod has been developed which meets the major weldment requirements—namely, a fully-nodular weld without postheat treatment when deposited by the normal oxyacetylene cast-iron welding technique, a weld having a Brinell hardness of 200 or under, a weld deposit having desirable mechanical properties, and a weld deposit having an excellent color match to the surrounding base metal. The basic chemistry of this new rod is similar to that of the general run of unalloyed nodular iron except that cerium rather than magnesium is the nodulizing agent. The rod is designed for use with the oxyacetylene method because usually no cast-iron rod can be expected to produce a deposit by arc-welding methods having hardness and other mechanical properties acceptable for most applications without heat treatment.

In studying the mechanical properties of the weld metal deposited by this nodular-cast-iron rod, all-weld-metal test samples were used with the exception of those for bend tests. Welds were prepared by joining 11- x 4- x 1-in. thick cast-iron plates beveled to an included angle of 90°. All-weld-metal 0.505 tensile and unnotched Charpy impact specimens were prepared from each weld. Because of the specimen length necessary for suitable bend tests, these of necessity included the base material on both sides of the weld. However, the bending action was centered entirely in the weld metal. Two types of cast-iron plates were used—a fully pearlitic gray-iron plate, and a commercial nodular-iron plate (also pearlitic). Both the gray and nodular-iron

Fig. 3 A bend test of 48 deg was made for this gas tungsten-arc weld which was annealed at 1600° F. For information on mechanical properties of the weld, see Table 2

base materials represented actual production irons.

Although this nodular-iron rod was designed primarily as an oxyacetylene welding rod, it was believed desirable to obtain some data on arc welding of the material. Samples were prepared using gas tungsten-arc welding on plates preheated to 1100° F. Initial efforts were made to complete these arc welds using multipass procedure. However, in practically every case, cracking occurred in either the heat-affected zone or in the weld metal, or in both. As a result of this experience, a special long-arc technique was developed, and the welding proceeded with the long arc in a manner that closely resembled the oxyacetylene technique. Mechanical tests were made only after annealing the arc welds. No effort was made to use these rods as a covered electrode for open-arc welding.

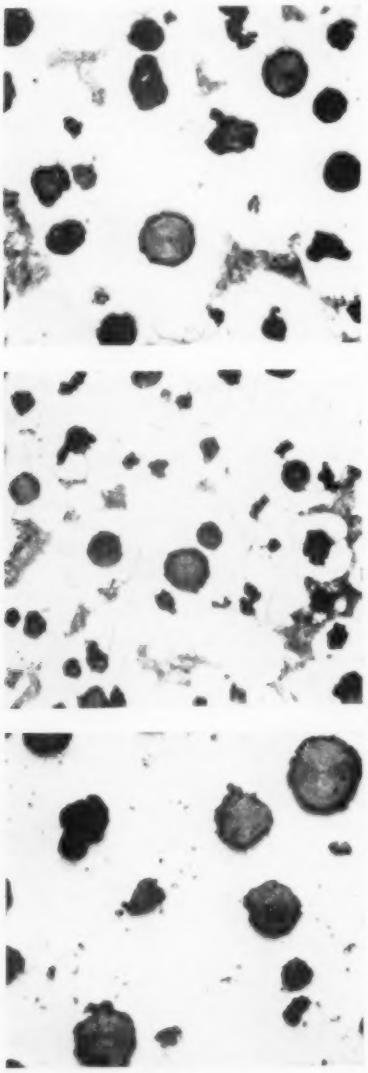


Fig. 4 Microstructures of three oxyacetylene welds are shown in the as-welded, stress-relieved and fully annealed conditions, from top to bottom, respectively. See Table 3 for mechanical properties

Most of the oxyacetylene welds were made without preheating the plates, because preliminary tests indicated that nothing was to be gained from the preheating. Normal oxyacetylene techniques allow sufficient preheating at the start and during progress of the weld on base-metal specimens of the size used. The mechanical tests were made on samples in the as-welded condition, as stress relieved at 1100° F, and as fully annealed at 1600° F. All samples prepared for mechanical tests were taken from welds joining two beveled plates.

Test Results

Figure 1 shows the microstructures of the two base metals used in this work, both in the as-cast condition. The nodular iron is a fully pearlitic material of unusually-high mechanical properties as shown in Table 1. No particular effort was made to obtain such high-strength material; in fact, in ordering these plates for the test work, no tensile range was specified. It just so happened that this is the material which was received. In spite of the high-strength figures, the elongation in 2 in. was high. The gray-iron base material was a high-strength pearlitic gray iron with an ultimate strength of 46,500 psi. As might be expected, no ductility could be recorded in the tensile tests on this material.

Figure 2 illustrates the structure of a typical gas tungsten-arc weld made with the nodular-iron welding rod before and after annealing. The as-welded structure reveals a considerable amount of nodular graphite surrounded by a ferritic matrix high in free-carbide content. Hardness readings over this area range from 35 to 45 Rockwell C (325–425 Bhn). This same weld material is annealed at 1600° F. The annealing treatment has transformed the rather hard carbide-bearing matrix into an almost completely-ferritic matrix containing nodular graphite. The hardness readings of this area have averaged 90 Rockwell B (185 Bhn).

An interesting set of tensile and elongation figures resulted from mechanical tests on a gas tungsten-arc weld after it was annealed at 1600° F. Results

Fig. 5 Bend tests made on these oxyacetylene-welded structures show a 58-deg bend and 18.75% bend elongation in 1 in. in the upper structure which was annealed at 1600° F, and a 42-deg bend and 14% bend elongation in lower as-welded structure

are shown in Table 2, while the tested weld is shown in Fig. 3. Because of the high hardness of the as-welded electric welds, it was not possible to machine mechanical test specimens. A bend through 48° and a bend elongation of 15% in 1 in. is revealed in the face-bend specimen shown in Fig. 3. This and the previous photograph appear to illustrate the very excellent and useful mechanical properties that can be obtained from a gas tungsten-arc weld with the nodular-iron rod, if the weld can be annealed.

The microstructures of three oxyacetylene welds are illustrated in Fig. 4: one as-welded, one stress-relieved, and one fully-annealed. The areas shown are approximately the center of the weld and are, without a doubt, all-weld-metal samples. One would not expect to see much difference in the microstructure between the as-welded and the stress-relieved material, nor would one expect any great difference in mechanical properties. This is illustrated in Table 3. The fully-annealed sample shows the expected drop in tensile properties and an appreciable rise in elongation. The bend elongations are also of interest. The bends were made on a standard guided-bend jig. The impact specimens used to obtain the values recorded were unnotched. Stress-relieving temperature was 1100° F, and the annealing 1600° F.

Figure 5 shows photographs of some

Table 3—Mechanical Properties of Oxyacetylene Welds

	As-welded	*Stress relieved, 1100° F*	*Annealed, 1600° F*
Ultimate Strength, psi	67,000	76,900	66,200
Yield Strength, psi	54,300	60,700	47,400
Elongation, % in 2 in.	3.5	6.75	12.5
Bend Elong., % in 1 in.	14.0	15.0	18.7
Impact Resistance, ft-lb	77.0	79.0	66.5

face-bend specimens in the as-welded and annealed condition. It was thought that this would be interesting to the reader to see the actual amount of bend that was typical of a number of such specimens made of oxyacetylene welded material.

Figure 6 is a photograph of two oxyacetylene welds with a hardness exploration across each. These particular samples were in both the as-welded and annealed condition. As can be seen by the hardness figures on the photograph, the hardness remains at a value well under the maximum for good machinability even in the heat-affected zone of the as-welded sample. The hardness of the weld metal is fairly low. This hardness exploration was made on a Rockwell superficial hardness tester, and the hardness readings were converted to Brinell scale as shown in this photograph.

The color match of the deposited weld metal with the surrounding base metal is also of interest. Figure 7 illustrates the close match which the oxyacetylene deposited weld metal makes with both the nodular iron and the gray base materials. This match is believed to be sufficiently close to either base metal to make this rod usable with either.

Figure 8 illustrates an interesting condition, which was revealed in one of the test specimens. For some reason, when this particular specimen was machined from the weld, an error was made so that a small amount of gray base material, together with some weld junction area, was included in the supposedly all-weld-metal sample. The top photomicrograph shows the structure of the pearlitic-gray-iron base material. In the center is the weld junction area showing some nodules and a considerable amount of broken-up flakes in what is frequently referred to as a "hot dog" structure with a rather high percentage of pearlite matrix. The bottom photomicrograph shows the structure of the all-weld metal with nodules surrounded by a ferritic matrix. Under tensile tests, this specimen failed at an ultimate strength of 55,300 psi. Elongation was negligible. The ultimate strength of the gray-iron base material was 46,500 psi. From the high failure strength of this test specimen, it is evident that the bulk of the strength was imparted by the nodular weld metal until that comparatively ductile material reached its elastic limit. The stretching of the nodular iron caused the break in the comparatively-brittle gray-iron material. Thus when elongation started, final rupture came almost immediately. The cross section of this specimen consisted of approximately 5% gray iron, 15% weld junction material, and 80% nodular weld metal. This indicates that a great deal of dependence can be placed upon a good nodular-iron weld even though mixed with areas of the less-ductile types of iron; and that as long as the yield point of the ductile iron is not reached, it will retain the load for the composite mixture without failing. However, as soon as the yield point of the nodular iron is reached, failure can be expected immediately.

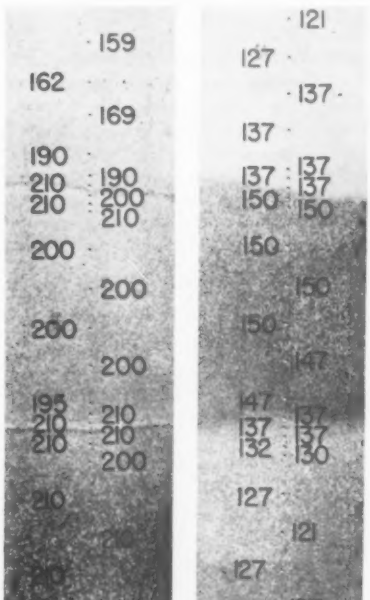


Fig. 6 Brinell-hardness exploration for nodular base material in the as-welded condition (*left*), and as annealed at 1600° F are shown on the photographs

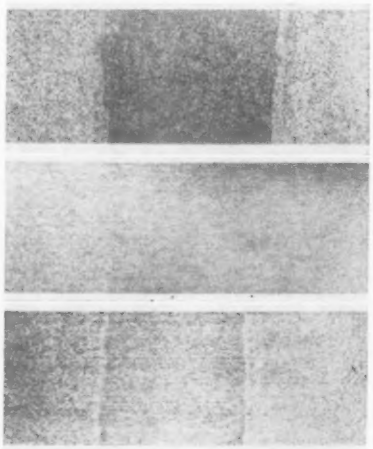


Fig. 7 Color-match specimens of oxyacetylene-deposited weld metal are shown. Top and center photographs show the as-welded and annealed conditions in nodular-iron base, while the bottom photograph shows the as-welded condition in gray-iron base

Potential Applications

One can only speculate on the uses to which a rod of this type can be put. Present belief is that the vast bulk of the material will find use as a filler material for weld repairing of nodular-iron castings. However, there is no reason why the same rod would not be equally as acceptable for weld repairing of high-strength gray-iron castings. The excellent mechanical properties of the material lead one to believe that it would fit that picture as well as the nodular-iron castings. While there has been no opportunity to try it, this does suggest the possibility that a rod of this

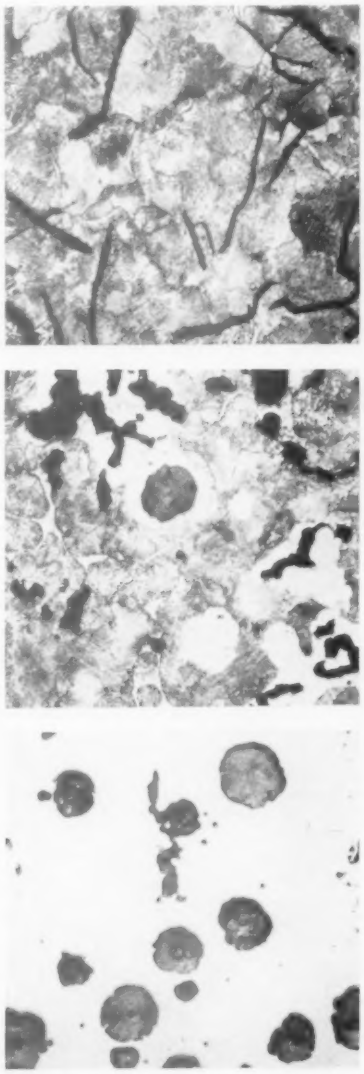


Fig. 8 This oxyacetylene weld specimen failed at an ultimate strength of 55,300 psi under tensile tests. From top to bottom, photomicrographs show pearlitic-gray-iron base material (approx. 5%), weld junction (approx. 15%), and all-weld metal (approx. 80%)

nature would also find use for the welding repair of pearlitic malleable-iron castings. Again, the very acceptable mechanical properties—both high strength and reasonable ductility—lead one to believe that this may be another possible field of usefulness for this type of rod.

The rod also has excellent possibilities as a material for fabricating (by welding methods) assemblies made up of components of nodular cast iron. If the fabricated assemblies are small enough to be annealed completely, this particular rod should prove an excellent material for this use. However, even in the as-welded condition, the mechanical properties of these welds made with this particular iron welding rod indicate the usefulness of this material, even when annealing or other postheat treatments are impossible. Where annealing is impractical, it appears that the assembly should be made by the oxyacetylene welding method unless it is a type of structure in which some embrittlement of the heat-affected zone and a low ductility can be tolerated. Where anneal is possible, it is entirely probable that either oxyacetylene or electric welding can be successfully used as a means of fabrication.

Summary

Data presented here have shown that a nodular-iron welding rod of suitable chemistry, under proper oxyacetylene welding technique, can form a weld metal bead of a fully nodular ferritic iron structure. The hardness of the deposited metal will be 200 Bhn or under. Its mechanical properties will be acceptable for most applications in the as-welded condition. When annealed, its tensile strength is reduced but ductility is increased.

When welded by the gas tungsten-arc process, the as-welded deposit was hard and difficult to machine. Annealing at 1600° F produced a fully-nodular and ferritic material with good tensile strength and ductility. When welded under good oxyacetylene technique, no hard constituents could be found in the weld metal, weld junction material, or heat-affected zone of the base material. Gas tungsten-arc welding did produce hard constituents in the weld metal and in the heat-affected zone. As stated above, annealing completely eliminated such constituents.

It has been the purpose of this work to develop nodular iron which will produce welds in the 50,000 to 75,000 psi ultimate strength range and with elongation in the 5 to 10% range, both properties in the as-welded condition. That objective has been reached. Improvement is a possibility and presents a challenge for further work.

At the present time, the rod has been made only on an experimental or pilot plant basis. It is expected that techniques used to produce the experimental rod can be easily adapted to production operations. Until this is done, however, the rod should be considered solely as an experimental item.

RESULTS OF SOME BRITTLE FRACTURE TESTS

BY F. HEBRANT, H. LOUIS, W. SOETE AND A. VINCKIER

The tests described in this paper were made to simulate multiaxial stress conditions encountered in highly stressed structures, for example, at hatch corners and at knees of Vierendeel trusses. Three types of specimens were used: (1) diagonal butt welds, (2) patch welded into a rigid ring and (3) crosses. Some of the steels are described in Table 1. JSC25 has high weldability, while CECM25 corresponds with average weldability. CECM20 does not satisfy Belgian weldability specifications, because the ratio of Kv to Ki is less than 0.6.

Abstract by **Gerard E. Claussen** of "Resultats de Quelques Essais de Rupture Fragile Considérés du Point de vue du Constructeur," published in *Revue de la Soudure*, No. 1, 20 pp. (1957).

Dr. Claussen is associated with the Development Laboratories, Linde Co., Newark, N. J.

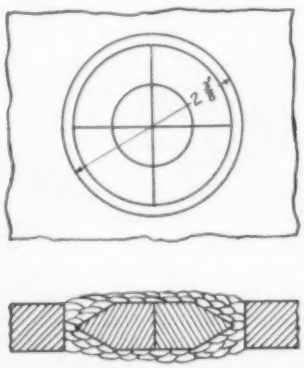


Fig. 1 Artificial defect used in patch tests

Diagonal Butt Welds

To cause spontaneous brittle fractures without applied stress, butt welds were made diagonally across plates 14 in. square. An artificial defect of the type shown in Fig. 1 was welded into the middle of the weld. The defect consists of a circular disk 2 3/8 in. diam split into quarters. Upon cooling the defect locally with liquid air, cracks were observed in the plate perpendicular to the weld.

Patch Welded into Rigid Ring

A circular patch 16 in. diam was welded into a ring restrained by four reinforcing rings 6 1/4-in. total thickness, 9-in. radial width. Two reinforcing rings were bolted to each side of the steel to be tested. The welded joints were of the X or K butt type or were

(*Continued on page 418-s*)

Table 1—Some of the Steels Used in the Tests

Steel	*CECM20*	*CECM25*	*JSC25*
Carbon	0.130	0.190	0.185
Manganese	0.693	0.470	0.530
Silicon	0.122	0.080	0.070
Sulfur	0.029	0.033	0.036
Phosphorus	0.017	0.018	0.021
Nitrogen	0.006	..	..
ASTM austenitic grain size	7	7	7
Yield strength, psi	34,700	32,000	29,400
Tensile strength, psi	56,300	57,000	55,600
Elongation, % in 4 in.	28	29.1	34.2
Mesnager impact value Ki mkg/cm²	17.17	21.8	18.9
Mesnager impact value Kv mkg/cm²	7.12	5.12	12.4
Mesnager impact value Kv/Ki	0.415	0.235	0.655
Charpy V-15 ft-lb transition temperature, ° F	−22	+32	+5
Charpy V-15 ft-lb value at 32°F, ft-lb	66	15	29
Charpy V-15 ft-lb value at −4°F, ft-lb	32	about 6	8
Robertson arrest of brittle fracture, ° F	+14	..	..
Thickness, in.	3/4	1	1

STRESS CORROSION OF TITANIUM WELDMENTS

Investigation indicates that chlorinated hydrocarbon solution causes the development of stress corrosion cracks when placed in contact with RC A110 AT titanium alloy at 700°F

BY RUSSELL MEREDITH AND W. L. ARTER

Introduction

Today's aircraft and missiles must fly at speeds which demand construction from materials that can provide sufficient strength at elevated temperatures. The development of satisfactory materials is more and more becoming the key factor in the production of advanced designs.

Figure 1 is a photograph of an experimental test missile built by North American Aviation which illustrates the aerodynamic configuration of this type of aircraft. Titanium alloys are a group of materials which show much promise in these applications.

For the past several years, N.A.A. has been conducting a program to evaluate the feasibility of producing guided-missile components from high strength, weldable titanium alloys.

As part of this program, a prototype tank containing both resistance and fusion welds was fabricated and tested both at room and elevated temperatures. The elevated temperature test produced weld cracking of sufficient magnitude to cause the failure of aircraft components. This paper contains a summary of the investigation made to determine the cause of the weld cracking.

Russell Meredith is associated with Missile Development Div., North American Aviation, Inc., Downey, Calif., and **W. L. Arter** is with Air Reduction, Pacific.

Presented at 1957 AWS National Spring Meeting, April 8–12, Philadelphia, Pa.

Material

The test tank was constructed from RC A110 AT titanium alloy. The material is an alpha alloy containing aluminum and tin as primary alloying elements.

Test Tank

Figure 2 is a photograph of the test tank. All fusion welding was done by the tungsten-arc process using argon cover and backing gas. Welds number 1 through 6 were made automatically, with no filler added, using full backing and hold-down tooling. Welds number 7 through 9 were made manually, with the addition of commercially-pure filler wire.

Tank Testing and Results

Physical testing of the completed tank included hydrostatic pressure testing and tension-compression loading parallel to the longitudinal axis of the tank at room temperature. In addition, the tank was hydrostatically tested at 700° F.

The room-temperature tests produced no weld failures. For the elevated temperature hydrostatic test, a chlorinated hydrocarbon was selected as the pressurizing medium because of its nonflammability and low vapor pressure at elevated temperatures. The tank was filled with this liquid and slowly brought up to a temperature of 700° F over a period of 8 hr. With the tank at temperature, hydrostatic pressure was applied, and immediately numerous weld failures occurred. These consisted almost entirely of transverse weld cracks propagating extensively into base metal. Figure 3 is a photograph of the end view of the tank showing the dye penetrant indications of the cracks produced by the elevated temperature test. A marking fluid was used to circle the crack indications so the cracks could be permanently located. It can be noted that cracks developed in both the fusion and resistance spot welds.

Metallurgical Investigation

Figure 4 is a photograph showing a close-up of transverse weld cracks in the tank. It can be seen that the cracks on both corner and butt welds propagated well into base metal. Figure 5 shows the microstructure of the cracked areas

Fig. 1 Experimental test missile

Fig. 2 Welded test tank

Fig. 3 Cracks in tank end after test

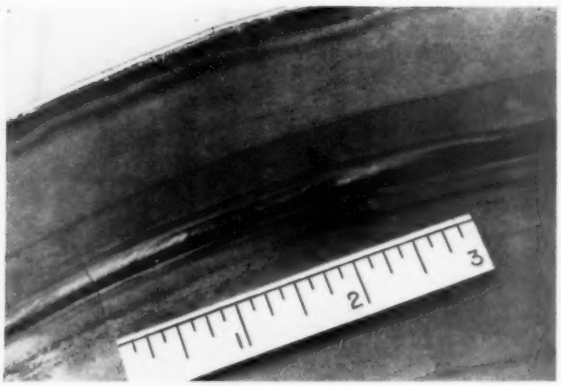


Fig. 4 Transverse cracks in fusion welds

at three locations in a corner weld which failed.

It was felt that the cracks could be attributed to one of the following three causes: (1) embrittlement of the welds caused by improper welding technique. (2) embrittlement of weld and base metal due to elevated temperature aging, and (3) stress-corrosion cracking resulting from high stresses and contact with a chlorinated hydrocarbon at elevated temperatures.

To determine if embrittlement had occurred due to contamination during welding or due to elevated temperature aging, bend tests, micro-hardness tests, and notched and unnotched-specimen tensile tests were made on weld and base material cut from the failed test tank.

Transverse-weld bend tests established a weld-joint minimum bend radius of 4.5 to 5.0t. Bend tests run on base metal established a minimum bend radius of 2.5 to 3t. These values are well within the range normally encountered in this material, in both conditions.

Micro-hardness traverses were performed across several fusion and spot welds. No abnormal hardness was displayed by either base metal or welds.

Notched and unnotched tensile specimens were prepared from both base metal and fusion welded joints. These specimens were tested at room temperature and at 600° F. The results showed no indication of embrittlement of either base metal or weld.

In addition to these tests on material cut from the failed tank, to further substantiate the conclusion that elevated temperature aging had not caused the weld cracking, circular patch weld-restrained bend specimens of the type illustrated in Fig.6 were aged by heating in air at 700° F for 3 hr. None of these specimens developed cracks.

After reviewing the results of the bend, hardness and tensile tests on material cut from the tank, and the circular patch weld-restrained bend tests on material of the same nominal analysis, it was concluded that embrittlement due either to weld contamination or elevated temperature aging was not the cause for the failures.

Restrained Bend Tests

To determine if the cracks were caused by stress corrosion, circular patch weld-restrained bend specimens in the following three conditions were immersed in a chlorinated hydrocarbon at 700° F: (1) in the stress-relieved condition, (2) in a condition in which moderate induced stresses were present, and (3) in a condition in which high induced stresses were present.

The first group of circular patch weld-restrained bend specimens tested in chlorinated hydrocarbon at elevated temperatures were those same speci-

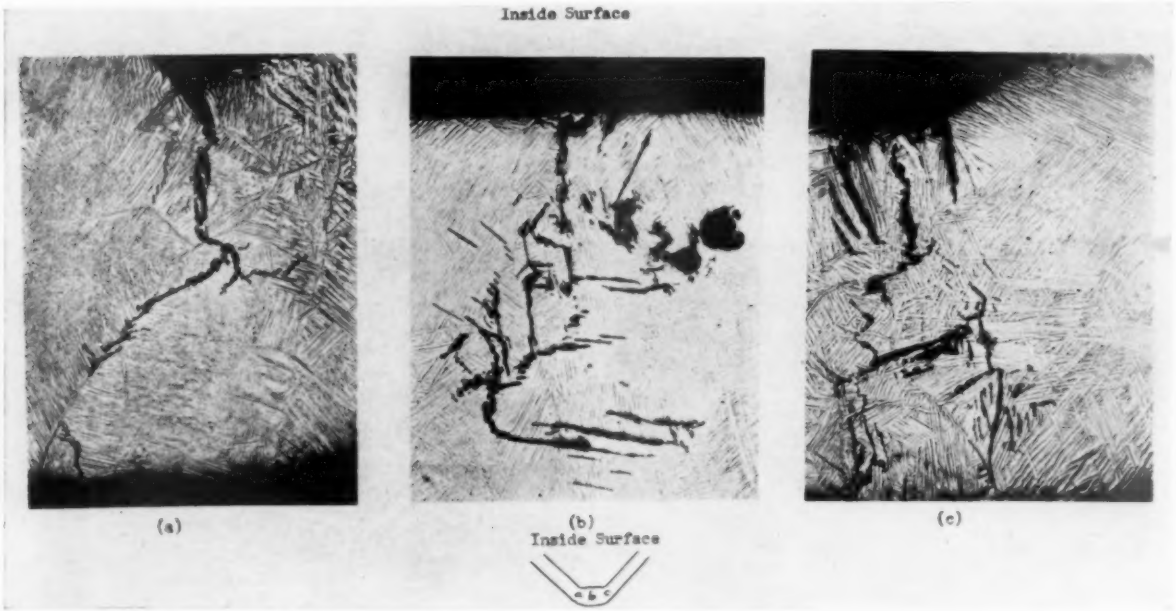


Fig. 5 Microstructure of cracked corner welds

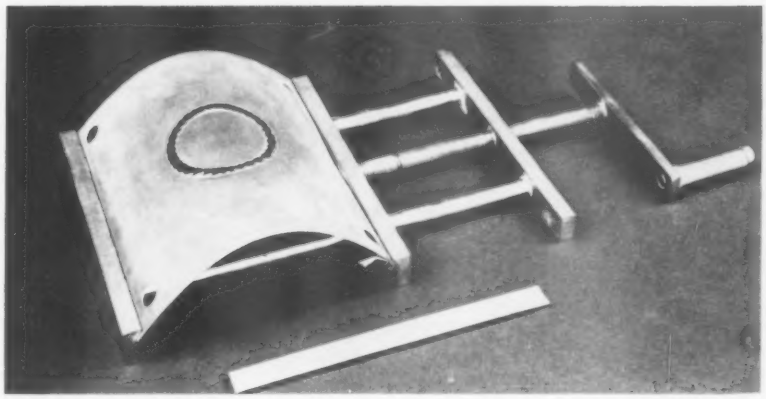


Fig. 6 Circular-patch weld restrained-bend specimens

Fig. 7 Cracked circular-patch weld

mens that had been aged at 700° F in air. (Induced and residual stresses had been partially relieved by the elevated-temperature treatment). After immersion in the chlorinated hydrocarbon solution for three hours at 700° F; all of the specimens cracked. The cracks which developed showed a tendency to follow the direction of rolling, as shown in Fig. 7. A metallographic comparison was made of the cracks which developed in these specimens with the cracks which were produced in the test tank. It can be seen in Fig. 8 that the cracks which occurred in both cases were similar.

Additional tests were made to more firmly establish these results. New circular-patch weld restrained-bend specimens were made. Half of the specimens were stress relieved, in the restraining fixtures, for a minimum of 1 hr at temperatures ranging from 1050° to 1300° F. The other half of the specimens was stress relieved in the as-welded condition to remove residual stresses due to welding. High stresses were then induced in these latter specimens by placing them in the restraining fixtures. All of the specimens were then immersed in chlorinated hydrocarbon solution at 700° F for 3 hr.

None of the stress-relieved specimens developed cracks, but all of the specimens containing induced stresses failed.

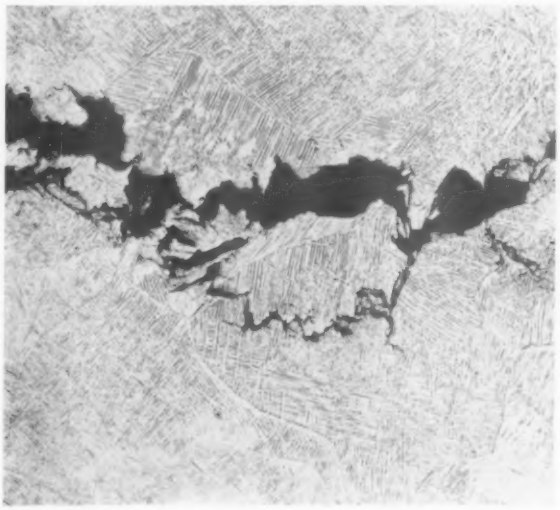
In addition to these tests on circular-patch weld specimens, base-metal specimens were restrained and tested in chlorinated hydrocarbon solution at elevated temperatures. These tests were run both at N.A.A. and at the laboratory of a titanium producer. None of those specimens tested at N.A.A. failed. Half of the specimens tested at the producer's laboratory developed cracks.

Analysis of Restrained Bend Test

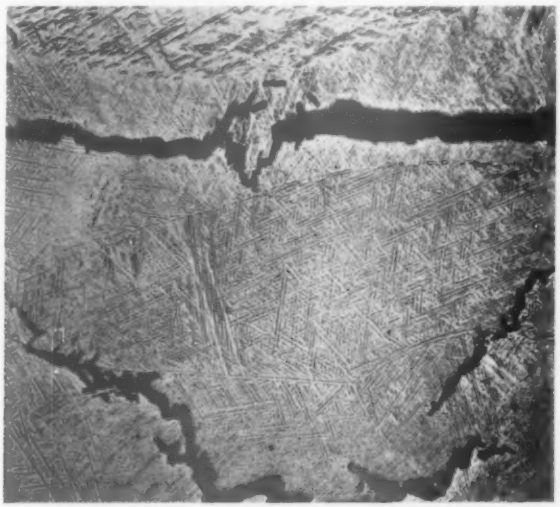
The following factors were taken into account in analyzing the results of the specimens tested in chlorinated hydrocarbon solution at elevated temperatures: three types of specimens containing three levels of stress were tested.

The circular-patch weld specimens which had been stress relieved in the restraining fixtures contained the minimum amount of induced stress. None of these cracked. The circular-patch weld specimens which were placed in the restraining fixtures, after stress relief to remove residual welding stresses, contained the maximum amount of induced stress. All of these cracked. The stiffening provided by the welded patch created high localized stresses which were not present in the restrained base metal specimens. Therefore, these latter specimens contained an intermediate amount of induced stress. Approximately 25% of these cracked.

After reviewing the results of all tests it was concluded that the chlorinated hydrocarbon solution was directly responsible for the failure of the test tank. Since a correlation appeared to exist between the stress level and the



Test Tank, 200 X



Circular-Patch Weld, 200 X

Fig. 8 Microstructure of cracked welds in tank and circular-patch welds

susceptibility to cracking, it was decided that the mechanism of failure was directly related to stress corrosion cracking.

Discussion on Various Test Media

The exact mechanism of failure is not known, but it seems likely that the free HCL present in the chlorinated hydrocarbon solution, after prolonged heating, is responsible. The solution used in testing was found to contain 0.017% free HCL. It has been reported that a 10% aqueous solution of HCL at 95° F causes stress-corrosion cracking of titanium stressed to 90% yield strength. In this work the cracks were found to follow long stringers of intergranular beta phase. In the work reported in this paper the cracks did not appear to be related to the microstructure. In most cases they were transgranular. The reason for the pronounced tendency of the cracks to follow the direction of rolling has not been determined.

Because of the severity of the failure of this tank it was deemed advisable to investigate whether or not other fluids, used in both missile fuel and hydraulic systems, might have a similar effect on titanium weldments.

In this portion of the investigation base-metal specimens and specimens containing weld joints were subjected to various levels of induced stress and exposed to various fluids at elevated temperatures. Specimens of all of the commercially available alloys in both sheet and bar stock were tested. None of the specimens developed cracks, and it was therefore concluded that stress-corrosion cracking of the type that caused the failure of the test tank would not be encountered in the application of titanium alloys to missile use.

Conclusion

While the work covered in this paper showed that (1) the tank failure was caused by a medium which would not come in contact with titanium components during the service life of a missile, and (2) fluids which will come in contact with missile components do not produce a similar type of failure, the significance of these data is not limited to this particular application.

Titanium is often selected in applications which require a metal with excellent corrosion resistance. This work points out that, while the resistance of titanium to normal corrosion by a particular medium may be good, if high stresses are present in the structure, the susceptibility to stress-corrosion cracking should be investigated.

RESULTS OF SOME BRITTLE FRACTURE TESTS

(*Continued from page 414-s*)

lap welds. Low-hydrogen electrodes $^1/_8$ and $^5/_{32}$ in. diam were used to avoid cracks. Measurements of shrinkage stresses showed 14,000 psi tension at the center, 21,000 psi radial tension in the weld, 28,500 psi maximum radial tension in the ring several inches outside the weld, and a maximum tangential tensile stress of 43,000 psi, which was found in the weld.

(*a*) A specimen was prepared using CECM20 for patch and ring with a milled notch at the center of the patch, and was cooled uniformly to −54° F. A hammer blow at the center caused no cracks. A hammer blow on the weld caused a few tiny cracks. Another specimen was prepared with an artificial defect welded into the weld. Cooling the defect locally to −54° F caused long cracks in three directions. The temperatures at the ends of the cracks were estimated from temperature distribution studies to be −8° F for the radial crack and −6 and −26° F for the other cracks. A reduction in thickness of 2.5 to 3.0% was measured at the ends of the cracks. The cracks curved toward compression zones. Although the thermal tensile stresses created by the liquid air were superposed on the residual stresses due to welding, the fact that the cracks stopped at temperatures lower than the Robertson temperature meant that they entered compression regions.

(*b*) This was similar to (a) but without milled notch. Cooling with liquid air caused a small crack at the artificial defect without a hammer blow. The stopping temperature was +27° F. A light tap with a hammer caused three long cracks. The stopping temperature was +18° F for the radial crack and +18 and −6° F for the other cracks. The reduction in thickness was 5 to 7% for the +18° F cracks and 1.8% for the −6° F crack. One crack followed a saw-tooth path, and the axis of the chevrons was closer to one surface of the plate than the other. The pattern of shrinkage stresses was believed to be eccentric.

(*c*) This specimen was made of JSC25 with an artificial defect welded into the center of the patch after the patch was butt welded to the ring. After the specimen had been cooled uniformly to −13° F, a hammer blow on the artificial defect caused a crack only $4^3/_4$ in. long which stopped in a region of high-tensile residual stress. Later local cooling caused another longer crack that spread across the ring into the compression zone. The stopping temperature was −22° F.

(*d*) The ring was CEM20 while the patch was made of steel LF20 having a Charpy V-transition temperature of +64° F. The patch was butt welded to the ring after an artificial defect had been welded into the center of the patch.

(*Continued on page 428-s*)

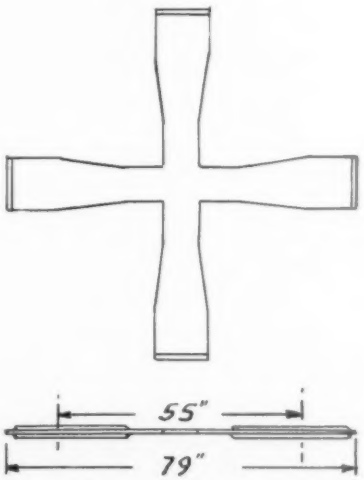


Fig. 2 Cross-shaped specimen for biaxial stress tests

Table 2—Biaxial-Stress Tests on CECM20 Steel

Type of corner	*Test temperature, ° F*	*Type of fracture*	*Fracture stress, psi*
Sharp	−202	brittle	68,500
Welded, rounded	−184	brittle	52,000
Sharp + crack stoppers	−184	brittle	65,000
Sharp + notch	−45	brittle	45,500
Sharp + notch	−40	brittle	44,000
Sharp + notch (with crack stoppers)	−27	brittle	47,000
Welded, rounded + notch	−13	ductile	42,000
Rounded + notch	+27	ductile	44,000

THE EXPERIMENTAL DETERMINATION OF BONDING TEMPERATURE

Graphic method used to determine the bonding temperature for three filler alloys

BY GREGORY BLANC AND R. D. WASSERMAN

Introduction

The temperatures encountered when joining parent materials with lower melting filler alloys have been a matter of conjecture for some time. In particular, this question has been the subject of debate in the International Institute of Welding's Subcommittee on Brazing and Surfacing.

Definition and Theory

In Europe, two concepts are in current use relative to defining base metal temperature. In France, the term "wetting temperature" is employed whereas "working temperature" is the terminology used in Germany.

Working temperature is defined as the minimum temperature which must be attained at the surface of contact between the base metal and the molten filler metal in order that the filler alloy can spread, flow and bond with the base metal.

Wetting temperature is the temperature to which the base metal must be raised in order that the molten filler metal can then wet the base metal i.e., spread, flow and bond with the base metal. This temperature is a function of the filler alloy, the base metal and the mode of operating technique.

The two temperatures are measured on the base metal. The essential distinguishing feature is that the wetting temperature is measured *before* the molten filler alloy enters into contact with the base metal, whereas the working temperature is measured *after* this contact has taken place. The filler metal has at this point imparted heat to the base metal.

The working temperature is independent of the base metal; it is a characteristic of the filler alloy. It is higher than the solidus of the filler metal and may be equal to the liquidus or slightly lower or higher than the latter depending on the filler metal involved.

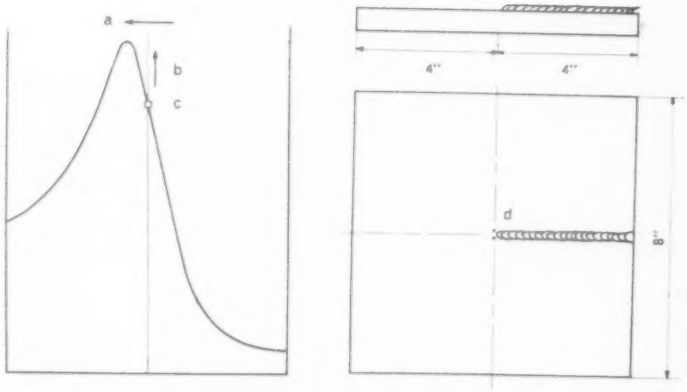


Fig. 1 Temperature variation during brazing

The temperature noted at the moment when the front of the bead is just going to touch the thermocouple is the bonding temperature.

a—direction of brazing
b—temperature
c—bonding temperature
d—thermocouple

In the case of a silver bearing copper-zinc-nickel filler alloy the working temperature is about 1650° F. The wetting temperature depends on the filler alloy, the base metal and the operating method: it is characteristic for the operation of brazing as a whole. In general, it is lower than the liquidus of the filler metal. The wetting temperature may be comprised between certain limits; the lower limit corresponds to the minimum temperature at which a bond will still be obtained, whereas the upper limit corresponds to the working temperature.

The concept of "bonding temperature" is of next importance. It is defined as the lowest temperature to which the base metal must be raised in order to obtain a bond with the molten filler metal. In general, it is lower than the solidus of the filler alloy. When linked together, the concepts of wetting and bonding temperature make it apparent that the bonding temperature is no other than the lower limit of the wetting temperature. This conclusion is of the utmost importance since the bonding temperature is no other than the lower limit of the wetting temperature. This conclusion is of the utmost importance since the bonding temperature and the lower limit of the wetting temperature are identical, it follows that the notion of bonding temperature is entirely justified.

Naturally, the concept of bonding temperature, identified as the lower limit of the wetting temperature, cannot be applied to every type of operation. Capillary brazing is made at the working temperature; i.e., above the solidus of the filler material.

In the case of braze welding and surfacing, on the contrary, the bonding temperature takes on its full significance. It tells the welder to what temperature he must heat the base metal at the joint in order that the filler metal can bond.

Gregory Blanc is Director of Research, Société des Soudures Castolin S. A., Lausanne, Switzerland and **R. D. Wasserman** is President of Eutectic Welding Alloys Corporation, Flushing, N. Y.

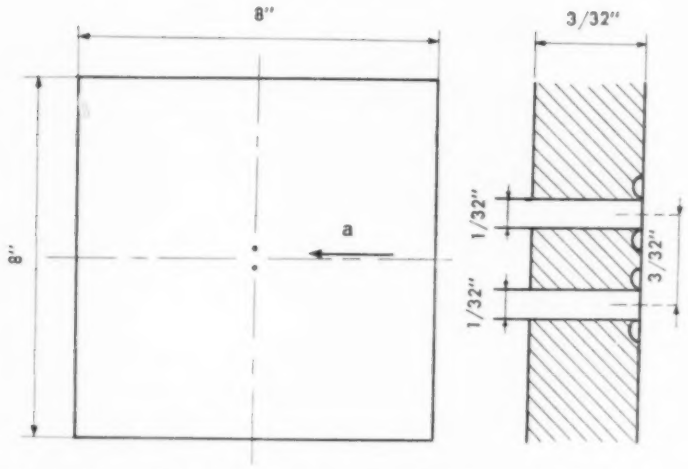


Fig. 2 Base-metal plate showing location of thermocouple

a—direction of brazing

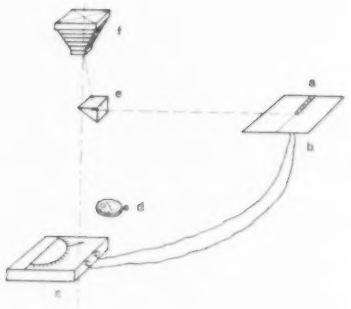


Fig. 3 Photographic method

Sketch showing arrangement of instruments.

a—base-metal plate with bead of filler meta
b—thermocouple connections
c—millivoltmeter
d—chronometer
e—prism
f—camera

Test Methods and Equipment

The bonding temperatures for various filler metals and the base metals have been checked recently at the request of the International Institute of Welding's Subcommittee on Brazing and Surfacing. The problem involved is that of depositing a bead of filler metal on the base metal and simultaneously recording the temperature in the base metal at a given point along the bead.

Assume that the base metal consists of an 8- x 8-in. square plate x $^{3}/_{32}$ in. thick on which a filler metal bead is deposited from right to left. If a thermocouple is mounted on the surface of the plate in the middle of the bead, the graph obtained will show the variations in temperature in the middle of the bead throughout the brazing process, as shown in Fig. 1.

It is known that the temperature distribution around the point where brazing takes place remains practically constant during the brazing operation, the temperature curve moving forward at the same rate as the brazing point. It follows that the temperature graph thus obtained also represents the variation in temperature, at a given moment, along the axis, depending on the distance from the thermocouple to the brazing point.

The shape of the graph illustrated in Fig. 1 is extremely interesting because it shows that the highest temperature at the thermocouple is not reached at the moment when the front of the bead touches the thermocouple, but later. The temperature registered at the moment when the front of the bead is just going to touch the thermocouple is, by definition, the bonding temperature.

Temperature measurements were made with Ni/Cr-Ni thermocouple calibrated by means of the usual fixed points up to a temperature of 1650° F. The base metal used was mild steel shaped into square plates 8 x 8 in. thick. In the middle of the plates, two holes of the same diameters as the thermocouple wires were drilled astride the bead axis; the distance between the holes being $^{5}/_{64}$ in. (measured at the axes). After being inserted in the holes, the wires were crimped in position and filed down level with the plate (Fig. 2).

To simultaneously record the three measurements involved—time, temperature and distance from thermocouple to front of bead—two methods were used. A photographic procedure was employed which involves photographing the base metal plate, a chronometer and the instrument showing the voltage of the thermocouple all together on the same negative while the bead is being deposited.

The layout adopted for the instruments is shown in Fig. 3 while Fig. 4 shows an image obtained in this way. Although filters and compensating developer baths were used to eliminate halo in front of the pool of filler metal as far as possible, difficulty was experienced in determining the position of the forward end of the bead with the required accuracy. We consequently found it necessary to use another method of measurement.

A second method utilized for time, temperature and distance measurements during bead deposition was by graphic means. A transparent horizontal screen is displaced in a direction parallel to the bead of filler metal by using an observa-

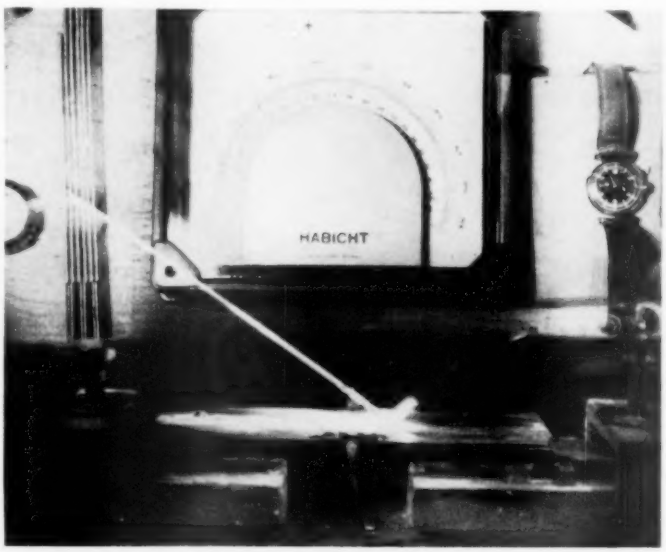


Fig. 4 Image registered by photographic method

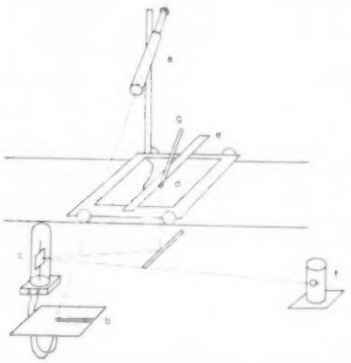


Fig. 5 Graphic method showing layout of instruments

a—dolly with screen and observation glass
b—bead of filler metal
c—galvanometer
d—spot
e—ruler
f—lamp
g—pencil

tion glass with reticule fastened to the screen in order to coordinate the two movements. The voltage from the thermocouple is applied to a mirror galvanometer, the spot from which is projected onto the same screen, where it moves up and down perpendicularly to the direction of movement of the screen (Figs. 5 and 6).

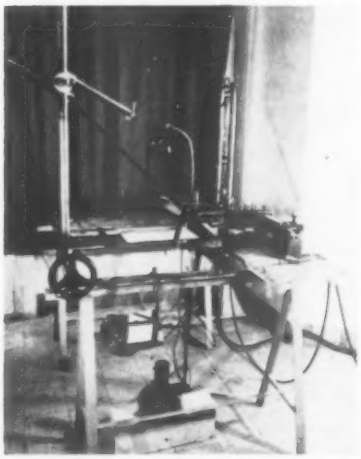


Fig. 6 Graphic method—view of layout adopted

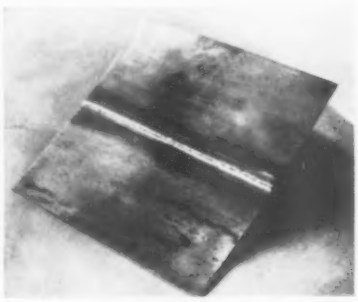


Fig. 7 Bead of filler metal deposited

Table 1—Analyses of Filter Materials

Alloy no.	*Cu*	*Zn*	*Ni*	*Ag*	*Cd*	*Sn*
1	45.23	43.52	10.50	0.75	...	...
2	59.65	38.58	...	0.65	...	0.93
3	17.50	15.07	...	40.35	27.08	...

Table 2—Mean Readings of Tested Alloy Systems

Filler alloy no.	*Acetylene, lt/hr*	*Brazing speed, in./sec.*	*Solidus, °F*	*Liquidus, °F*	*Maximum temperature, °F*	*Bonding temperature, °F*
1	approx. 50	0.049	1616	1652	1621	1431
2	approx. 50	0.049	1598	1625	1614	1368
3	approx. 50	0.0625	1139	1157	1263	1053

Table 3—Lower Limit of Wetting Temperatures

Filler alloy no.	*Solidus, °F*	*Liquidus, °F*	*Working temperature, °F*	*Bonding temperature, °F*
1	1616	1652	1652	1436
2	1598	1625	1634	1427

In this way, by following the spot with a pencil, the graph of the voltage variations in the thermocouple, or in other words the temperature graph, is drawn directly as the bead advances. Simultaneous registration of time is obtained by imparting a synchronized to-and-fro movement to a pencil, which will thus trace out a succession of sine waves as the screen moves forward. In this manner the observer is able to follow a well-determined point on the bead closely, allowing the relationship between temperature and bead travel to be established with the greatest accuracy.

Sighting was always done on the front of the pool of filler metal, i.e., on the most advanced point reached by the molten filler metal in the direction in which the bead is deposited. The position of the thermocouple is plotted on the paper before the graph is drawn.

In the graphic method described, the variation in temperature and therefore in the thermoelectric current by which it is measured, is extremely rapid. It was consequently found necessary to correct the readings indicated by the galvanometer, which lagged slightly behind the phenomena. Briefly, the angular movement of a measuring device is expressed by the equation:

$$N = E\frac{d^2\infty}{dt^2} + A\frac{d\infty}{dt} + W\infty$$

in which

N = the measured quantity
∞ = the angle of displacement
t = the time and
E, A, W = constants pertaining to the device

It follows that the greater are the

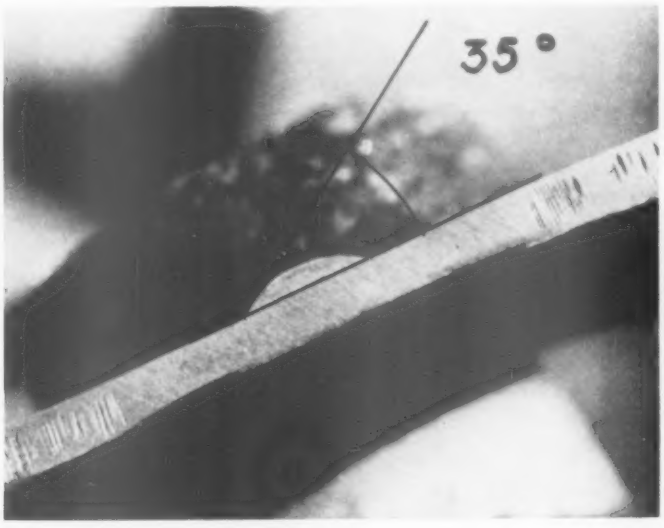


Fig. 8 Wetting angle

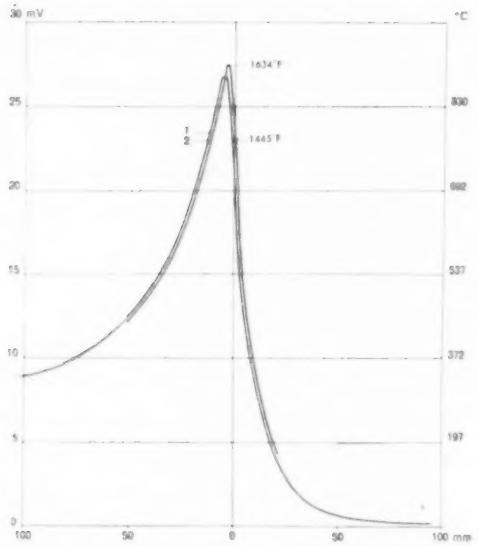


Fig. 9 Graphs showing temperature as taken down directly (1) and after correction (2): alloy No. 1 (see Table 1) on iron

Maximum temperature 1634° F
Bonding temperature 1445° F

speed and acceleration, the higher is the amount of correction that must be applied, expressed by the term:

$$E\frac{d^2\infty}{dt^2} + A\frac{d\infty}{dt}$$

This correction has been done in the case of all the graphs drawn, by means of a very rapid method of graphical derivation.

Materials Employed

Bonding temperature tests were run using three different alloy systems for filler materials. The fluxes employed for each alloy system were specifically designed for each filler material. Table 1 shows the analyses of the filler materials used in this investigation.

The base metal used for all tests was 8- x 8- x $^3/_{32}$-in. thick SAE 1010 mild steel plate stock.

Test Results

The experiments were carried out under the conditions encountered in practice. The bead deposited is illustrated in Fig. 7. The bond between the base metal and filler material was excellent, the wetting angle being not greater than 35° as indicated in Fig. 8.

Figure 9 shows an example of the temperature graph as plotted directly and also the corrected graph.

Table 2 shows the mean readings obtained with the three alloy systems tested. The results prove conclusively that the bonding temperature is considerably lower than the solidus and liquidus of each particular filler alloy tested.

Other experiments have produced results similar to those obtained by us. Thus, J. Colbus (Germany) for instance, obtained the results reported in Table 3 for the lower limit of the wetting temperature in braze welding, i.e., for the bonding temperature according to our definition.

In this connection, it is appropriate to mention briefly the importance of the flux used since only a flux of the correct chemical composition will insure a perfect bond at the bonding temperature. Moreover, recent experiments have shown that the spreading of the filler metal can be improved substantially by as much as fifty percent by adding appropriate active substances. The significance of this fact as far as the practical technique of brazing is concerned is evident.

Conclusions

By using high quality filler alloys and fluxes, it is possible to join metals without heating them to the wetting temperature of the filler metal. It is sufficient to heat the base metal to the bonding temperature.

The bonding temperature is the lowest temperature to which the base metal must be raised in order to obtain a bond with the molten filler metal.

The bonding temperatures can be measured with a sufficient degree of accuracy by means of the graphic method described in this test. In the case of the three alloys studied, it was ascertained that the bonding temperature is considerably lower than the solidus of the filler metal.

Correction:

"*A Comparative Study of Thoriated, Zirconiated and Pure Tungsten Electrodes*"

by L. P. Winsor and R. R. Turk

On page 113-s of the March 1957 issue of THE WELDING JOURNAL, *Research Supplement, the graphs for the two illustrations have erroneously been interchanged.*

The illustration labeled Fig. 2 in the paper should actually carry the caption "Fig. 1. Percent successful starts—flat-ended electrodes, high-frequency starting." The illustration labeled Fig. 1 should carry the caption "Fig. 2. Percent successful starts—flat-ended electrodes, touch starting."

The Editor

SPOT WELDING 65-35 BRASS ON SINGLE-PHASE EQUIPMENT WITH SLOPE CONTROL

Program conducted to set up specific requirements for spot welding of one-half hard yellow brass

BY L. E. MILLS AND H. C. WOLFE

Material Welded

The scope of this paper is limited to the spot welding of one-half hard yellow brass: 65% copper, 35% zinc. This brass has an ultimate tensile strength of 61,000 psi, and a hardness of Rockwell B57–74. It has twice the thermal conductivity and more than twice the electrical conductivity of 1010 steel. Other properties which made it a desirable material are the ease of soldering and silver brazing and its nonmagnetic properties. The work was limited to five material thicknesses: 0.032, 0.050, 0.064, 0.094 and 0.125 in. Both equal thickness and unequal thickness combinations were welded.

Equipment

The machine used was a 200-kva single-phase, air-operated, press-type spot welder, which has a maximum short-circuit secondary current of 60,000 amp at 14.7 volts. It is equipped with an up and down slope control, a dual pressure system with forge control and a S3H welding control (Fig. 1).

Schedules similar to those recommended have been established on 75-kva and 150-kva single-phase welders.

Cleaning Prior to Welding

Surface cleanliness is important for spot welding brass. Very poor consistency and appearance are obtained when the brass is not cleaned.

Either chemical cleaning or wire brushing is satisfactory. Strength consistency, nugget shape, and tip pickup were equivalent with either cleaning method. The chemical cleaning cycle consisted of four steps:

1. Remove all oil and grease by vapor degreasing.
2. Immerse for five to ten seconds in acid solution of two parts of sulfuric acid and one part of nitric acid to remove oxides.
3. Rinse immediately in cold water.
4. Rinse in hot water and dry with an air blast.

The surface resistivity of brass, unlike that of aluminum, is not much effected by hot water.

The wire brushing was accomplished with a fine stainless-steel brush.

The comparison of surface resistivity was made on the microhm meter shown in Fig. 2. The brass was easily cleaned to two microhms of surface resistivity. The resistivity builds up very slowly and, after four weeks, the maximum reading obtained was 115 microhms. Due to normal shop dirt and oil accumulation, it is recommended that the brass be welded within 48 hours after cleaning. Some means of material protection should be provided after cleaning and prior to welding.

Electrode Material

Recommendations were received which called for the use of Group A Class I, Group A Class II, and Group B Class 11 electrodes. The Class I electrodes were recommended to withstand the high current density required to weld brass. Group B Class 11 electrodes were recommended for hardness and the generation of more heat in the vicinity of the brass. Class II electrodes were recommended as a commonly used compromise.

All three electrode materials were evaluated and satisfactory welds were made with the three materials. Very significant differences appeared in the

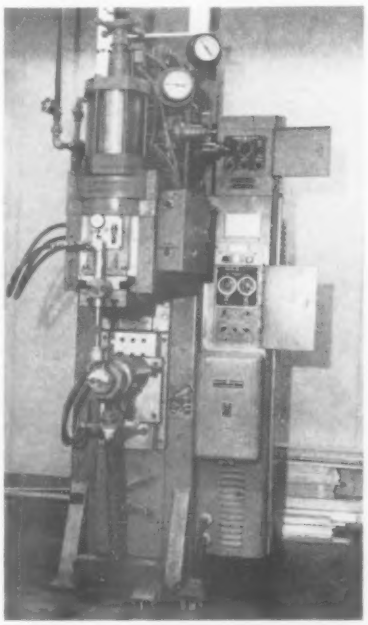


Fig. 1 200-kva single-phase air-operated press-type spot welder

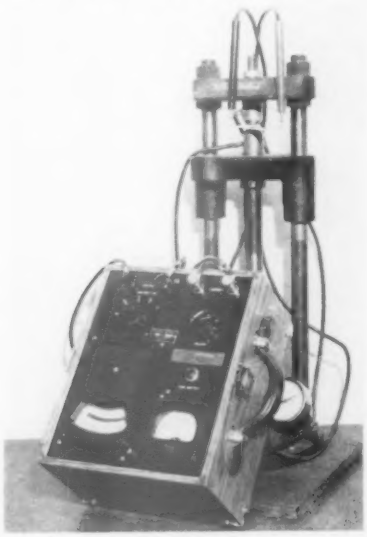


Fig. 2 Surface resistance meter

Two pieces of yellow brass are placed between two 4-in. spherical-radius-domed electrodes. A force of 1000 lb is applied to the electrodes. The meter current leads are attached to the electrodes. The voltage leads have pointed probes for electrical connection to the brass

L. E. Mills and H. C. Wolfe are associated with Materials & Processes Laboratory, General Electric Co., Syracuse, N. Y.

Presented at 1957 AWS National Spring Meeting, Philadelphia, Pa., April 8–12.

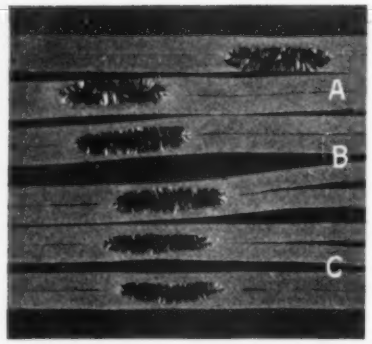


Fig. 3 Electrode material effect

Two pieces of 0.032-thick yellow brass. 5/8-in. diam electrodes were used. One electrode had a 3-in. spherical-radius dome and the other electrode was flat faced. Two spots are shown for each electrode material. (A) Group B, Class 11 material faced electrodes, (B) Group A Class II electrodes, (C) Group A Class I electrodes.
Etch: 2 parts Nitric Acid and 1 part Acetic Acid.

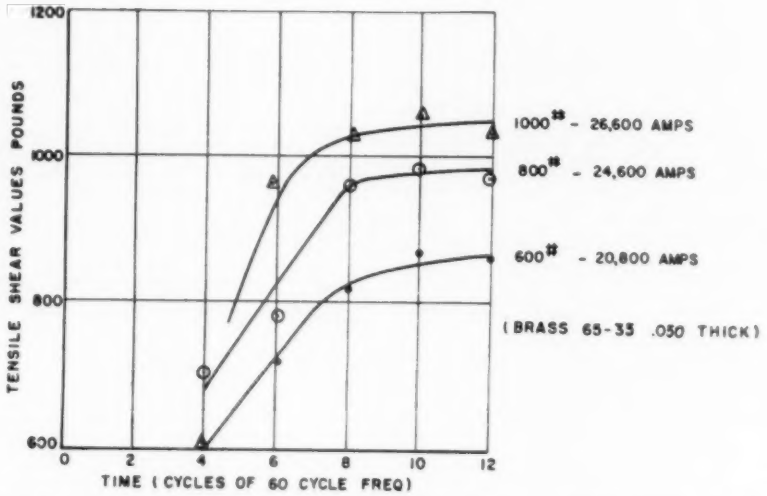


Fig. 4 Time vs. tensile-shear values at various pressures and max current at this pressure

nugget shape and position as shown in Fig. 3. Electrode force and welding time were maintained constant. The welding current was varied to produce welds with equivalent tensile shear strength. A slender nugget with little penetration was produced with the Group A Class I electrodes. A uniform football-shaped nugget with about 60% penetration was obtained with the Group A Class II electrodes. The Group B, Class 11 Elkonite electrodes produced a nugget with excessive penetration.

One other consideration which contributes to the choice of the electrode material is the number of spot welds which can be produced between tip cleanings. With each of the electrode materials, slight tacking occurred on the first three or four spots after dressing the electrodes. In each case, the tacking disappeared after a few spots were made, and no additional tacking or tip pickup occurred. Several hundred spot welds can be made between tip dressings. The only reason for dressing the electrodes was to retain the electrode shape. Therefore, a hard material should be used to limit the electrode deformation. Since the Group B, Class 11 electrode produced excessive penetration, it is recommended the Group A Class II material be used for electrodes.

In all cases, one flat electrode and one domed electrode were used. A three-inch radius dome was used on the #2 Morse taper electrodes, and a six-inch radius dome was used on the #3 Morse taper electrodes. A flat electrode is used in order to produce as smooth an appearance as possible on one surface of the work.

It is noted that when one flat electrode and one domed electrode are used, a slight curling of the weld nugget occurs. The curl is in the same direction as the dome on the domed electrode. This curling of the weld nugget becomes even more prevalent when combinations of unequal thickness are welded.

Welding Time

Time determination can be obtained from a curve of time vs. tensile-shear values. Various combinations of time and electrode force were used for each thickness combination to produce maximum tensile values without expulsion. Curves at the various electrode forces and time were plotted for each thickness under consideration. Figure 4 is a typical illustration showing time vs. tensile-shear values.

The slope of these curves shows a pronounced change from a steep slope for short-time welds to a relatively flat slope for a longer welding time. The knee in the curves appears at approximately the same weld time for each pressure.

If a short time is used, work will be on the steep portion of the curve, and poor consistency will result. Thus, the recommended time for each of the thicknesses will be the shortest time practicable beyond the knee of the curve.

The recommended time for each of the thicknesses is as follows: six cycles for 0.032, eight cycles for 0.050, ten cycles for 0.064, fourteen cycles for 0.094 and sixteen cycles for 0.125.

An attempt was made to find the effect of time on the nugget shape. The two constants maintained were the electrode force and the average tensile shear values. The welding current was changed with the welding time to produce equivalent tensile shear values. Times of two, four, six, ten, and sixteen cycles were used on 0.032–0.032 thick material. Figure 5 shows almost no change in the shape of the nugget, even though the time changed 800%.

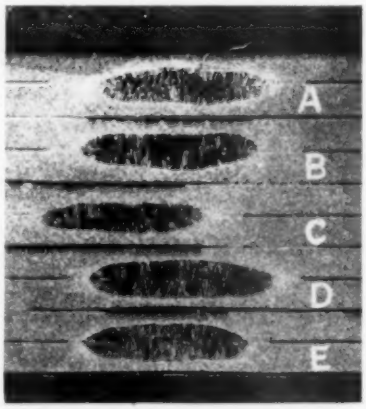


Fig. 5 Time effect

Two pieces of 0.032-thick material. Equivalent tensile-shear averages are produced at welding times of (A) 2 cycles, (B) 4 cycles, (C) 6 cycles, (D) 10 cycles, (E) 16 cycles. No change in nugget shape occurs even though the time changed 800%.
Etch: 3 Parts Nitric Acid and 1 part Acetic Acid.

Electrode Force

The nature of electronic products requires that a limit be set for the maximum allowable electrode force. Electronic components and small chassis result in difficult welding positions. Offset holders and offset electrodes are common requirements.

Several electrode forces were used for each material thickness combination. It was found that a large range of electrode forces could be used which would produce satisfactory results. At a low electrode force, a longer time at a lower current setting was necessary to produce results equivalent to those of high electrode force. The maximum current used in each case was just below

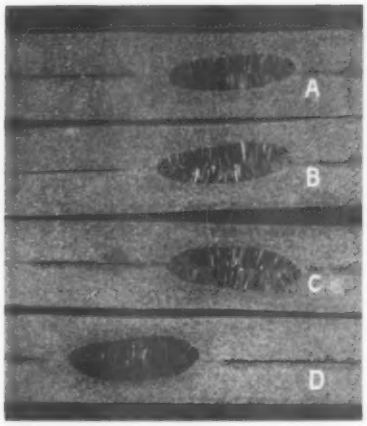


Fig. 6 Pressure effect

Two pieces of 0.064-thick stock. Equivalent tensile-shear averages are produced with pressures varying from (A) 1200 lb, (B) 1000 lb, (C) 800 lb to (D) 600 lb.

Etch: 3 parts Nitric Acid and 1 part Acetic Acid.

the current which would cause expulsion.

Spot welds were made at different electrode forces to produce equivalent tensile-shear specimens. Welding time was held constant while welding current was decreased as the electrode force was decreased, thus producing equal tensile-shear specimens. The effect of force is shown in the degree of penetration. This is illustrated in Fig. 6. The weld diameter stays relatively constant, as do the tensile-shear values. The penetration changes from 41% at 1200 lb to 61% penetration at 600 lb of electrode force on 0.064–0.064 thick brass. Thus, higher electrode forces will produce less penetration for equivalent strengths.

The force that was selected and recommended in the welding schedule is the lowest force which would produce void-free welds with good strength consistency.

Sheet separation was observed in all combinations. The only combination which appeared to present a sheet separation problem was 0.125–0.125 brass. Two thousand pounds of electrode force were required to produce less than 5% sheet separation.

Welding Current

The high electrical and thermal conductivity of 65–35 brass requires that high welding currents be used to produce a weld. Currents recommended for the various thickness combinations are shown in Table 4. The welding current that can be used before expulsion depends on the electrode force with little regard to the time of current flow. When welding two equal thicknesses of 0.032-in. material, approximately 20,400 amp can be used with 400 lb of electrode force; 23,500 amp can be used with 600 lb of electrode force; 26,400 amp of current can be used with 800 lb of electrode force. The current which may be used for two equal thicknesses of 0.125 material varies from 30,700 amp at 1200 lb of electrode force to 43,200 amp at 2000 lb of electrode force.

Table 1—Welding Current Variations

Brass, 65–35		½ Hard
(.064-in. thick to .064-in. thick)		
Welding time		8 cycles
Slope time		3 cycles
Initial current		40% of final current
Electrode pressure		800 lb

Welding current, amp	*Tensile-shear values*	*Consistency*	*Etch nugget diam, in.*	*Peel nugget diam, in.*	*Percent penetration*
18,000	0		0	0	0
18,500	600	+15%–14%	0.145	0.100	31%
20,700	1020	+8%–12%	0.185	0.155	39%
22,900	1313	+9%–4%	0.210	0.200	47%
25,900	1505	+5%–3%	0.240	0.235	61%
*27,200	1650	+6%–6%	0.255	0.260	75%

* Expulsion occurred.

The effect of current on the shape and size of the weld nugget is shown in Fig. 7. The welds shown are made in two pieces of 0.064-in. thick stock using three cycles of slope and eight cycles of weld time, and an electrode force of 800 lb with currents varying from 18,500 amp to 27,200 amp. The ratio of weld diameter to depth of penetration stays relatively constant. Table 1 lists several welding current values, with average tensile-shear values obtained, consistency of tensile-shear strength, etch diameter, peel diameter and percent penetration. Welding current above 26,000 amp produced expulsion.

Slope Control

Both up and down slope controls on the current were attempted. The method of evaluating the effect of slope control was by the tensile-shear strength consistency of the spot welds, by the tip pickup, and by the expulsion. Various values of slope time and current were used.

As described under the comments on the effect of welding current, there appears to be a maximum current that can be used for each thickness at a given electrode force, regardless of the length of time. This also applies when slope is used. However, the current used can be about four percent higher with slope than without. Also, resulting tensile-shear values before expulsion are higher when slope is used.

To determine the optimum slope setting, initial currents of 20 to 100% of the welding current were used. The tensile-shear values became more consistent and the nugget shape became more uniform as the initial current was decreased from 100 to 40% of the final welding current. Further decrease of the initial current produced no noticeable improvement.

Various up slope times of three to fifteen cycles were used. A short slope time was better than no slope. However, increasing the slope time beyond three cycles did not have any advantageous effect. When a long time slope was used, either a higher current or a longer time was required to produce results equivalent to the three-cycle slope.

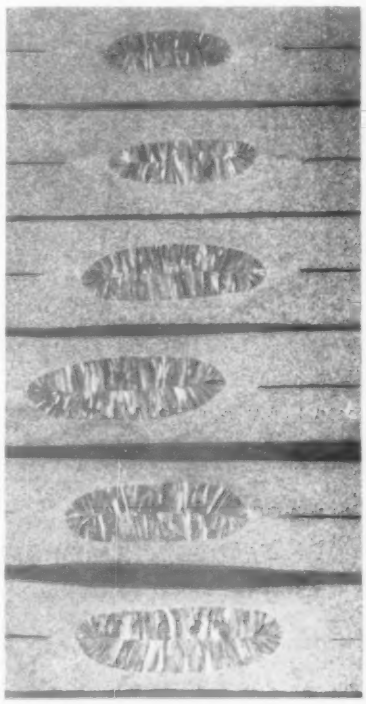


Fig. 7 Current effect

Two pieces of 0.064-thick stock welded at 800-lb electrode force; 8-cycles weld time; 3-cycles of slope with initial current 40% of final currents; welding current varies from 18,500 amp to 27,200 amp. The ratio of weld diameter to penetration stays relatively constant.

Etch: 3 parts Nitric Acid and 1 part Acetic Acid.

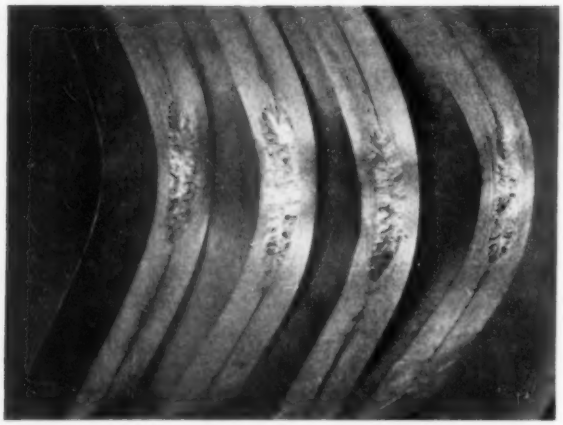


Fig. 8 Ductility test samples

Two pieces of 0.064-thick yellow brass. A $^1/_8$-in. wide section has been removed from the spot weld. The sections have withstood a 90% bend around a $^1/_8$-in. radius.
Etch: 3 parts Nitric Acid (HNO_3) and 1 part Acetic Acid (CH_3-COOH).

Fig. 9 Edge bulge cracks

Two pieces of 0.125-thick yellow brass. Three-quarters of an inch contact overlap produces edge cracks.

The use of a down slope did not appear to improve the tensile-shear strength or the nugget shape. Thus, it is not recommended that down slope be used in any of the welding schedules.

Up slope was used for all combinations. Three cycles of slope time with an initial current of 40% of the welding current was used in all schedules.

Forge Pressure

The use of forge pressure did improve strength consistency. It would be advantageous to use forge pressure during the flow of welding current where straight holders and electrodes can be used. However, for electronic-component welding where offset holders and offset tips are used, excessive skidding occurs. The result is an odd-shaped spot weld with excessive distortion.

Since consistent tensile-shear values were obtained without the use of forge, the schedules do not call for it.

Metallurgical and Appearance Requirements

A set of criteria has been established for spot welding brass. The external appearance of the weld shall have the following requirements. It should be smooth and free of pits, cracks or tip pickup. There should be no expulsion of metal between the sheets or from the surface of the sheet. Bulging or cracking of the edges should not be present. Sheet separation should be kept to a minimum and never be in excess of 10% of the thinner sheet. Surface indentation should be kept to a minimum and not allowed to exceed ten percent of the thickness of the sheet in which it occurs.

Weld penetration and soundness can be determined from the etched cross sections. A minimum penetration of 20% and a maximum penetration of 80% of the original sheet thickness are required. The welds must be free from cracks and essentially free of porosity.

A ductile weld is desirable and can be evaluated by removing a $^1/_8$-in. wide section of the spot weld and bending the weld area. The bend should be made in the direction of the plane of the weld nugget. There was no problem in obtaining welds that would withstand a 90 degree bend around a $^1/_8$-in. radius. A photograph of some ductile test samples is shown in Fig. 8.

Recommended Minimum Tensile-Shear Strength

The minimum average tensile-shear strength was obtained by producing a weld with a weld nugget diameter equivalent to two times the thickness of the thinner material plus $^1/_{16}$ in. The values are test-produced values, and not theoretical calculations.

The tensile-shear test produced a true shear of the cast weld nugget itself in all cases except in the 0.032-in. thick sheet. At this thickness, a nugget would be pulled from one of the pieces rather than the cast weld nugget being sheared.

In a majority of the tests which were performed, the consistency of the tensile-shear values was very good, even for different average values. There was no difficulty in obtaining consistency within plus or minus 10% of the average. This consistency is easy to maintain with $^1/_2$ hard yellow brass in the hardness range of Rockwell B57-65. It is more difficult to maintain consistency when welding $^1/_2$ hard yellow brass with a hardness above Rockwell B65.

It is required that a satisfactory welding schedule shall produce strength consistency of plus or minus 10% of the average value for 90% of the specimens tested and a maximum allowable variation of plus or minus 20% for the remaining specimens.

With the use of high electrode forces and long welding time, weld nuggets of much larger diameter than mentioned above were produced. Naturally, the tensile-shear values obtained with the larger diameter nugget were much higher than the minimum values recommended.

Table 2—Recommended Minimum Required Strength Per Weld for Spot Weld Shear Specimens for 65–35 Brass

Thickness of thinner sheet, in.	*Lowest average, lb*		*Absolute min, lb*
	20 Spots	*3 Spots*	
0.032	516	482	413
0.050	800	748	640
0.064	1063	994	850
0.094	1825	1708	1460
0.125	2925	2735	2340

Table 3—Recommended Design Practice for Spot Welding Brass

Thickness of thinner sheet, in.	*Min spot spacing, in.*	*Min contact overlap, in.*	*Min edge distance, in.*	*Design shear strength, lb*
0.032	$^5/_8$	$^1/_2$	$^1/_4$	330
0.050	$^5/_8$	$^5/_8$	$^5/_{16}$	512
0.064	$^3/_4$	$^3/_4$	$^5/_8$	680
0.094	1	1	$^1/_2$	1168
0.125	$1^1/_2$	$1^1/_4$	$^5/_8$	1872

Table 4—Spot-Welding Schedules for 65–35 Brass 1/2 Hard (Rockwell B57–74

Thickness, in.	*Pressure, lb*	*Time (cycles)*		*Current, (amp)*	
		Rise	*Total*	*Initial*	*Final*
0.032–0.032	600	3	6	9,400	23,500
–0.064	600	3	6	9,400	23,500
–0.094	600	3	8	9,000	22,500
–0.125	600	3	10	9,000	22,500
0.050–0.050	800	3	8	9,400	23,500
0.064–0.064	800	3	10	10,200	25,600
–0.094	900	3	10	10,400	26,100
–0.125	900	3	10	10,600	26,400
0.094–0.094	1000	3	14	10,700	26,600
–0.125	1200	3	14	12,400	31,100
0.125–0.125	2000	3	16	17,300	43,000

Table 2 lists the compiled recommendations for tensile-shear values. It follows very closely a system used by the Military Departments for steel alloys. The recommended minimum average for twenty spots is the average which is obtained by the above method of producing a nugget two times the thickness of the thinner material plus one-sixteenth of an inch. The minimum average for three spots (which is the normal shop quality control) should be 6.5% lower than the minimum average for twenty spots. The absolute minimum shall be 20% lower than the minimum average for twenty spots.

The recommended design strengths are listed in Table 3. This design strength is 80% of the absolute minimum allowable strength of Table 2.

Contact Overlap and Spot Spacings

The determination of minimum contact overlap and spot spacing was accomplished in two ways. Strips 3 x 36 in. were welded at various contact overlaps and spot spacings. Also, to allow close spot spacing tests, two pieces 1 x 4 in. were welded with two spots. A saw-cut was then made between the spot welds through one piece to allow testing of the second spot only. More accurate results were obtained with this procedure since it was possible to use wide coupons to test close spot spacing. Results of the spot-spacing data are plotted (Fig. 10) for 0.032, 0.063 and 0.125-in. thick material. Also noted in Fig. 10 is the tensile-shear value obtained for an individual spot weld.

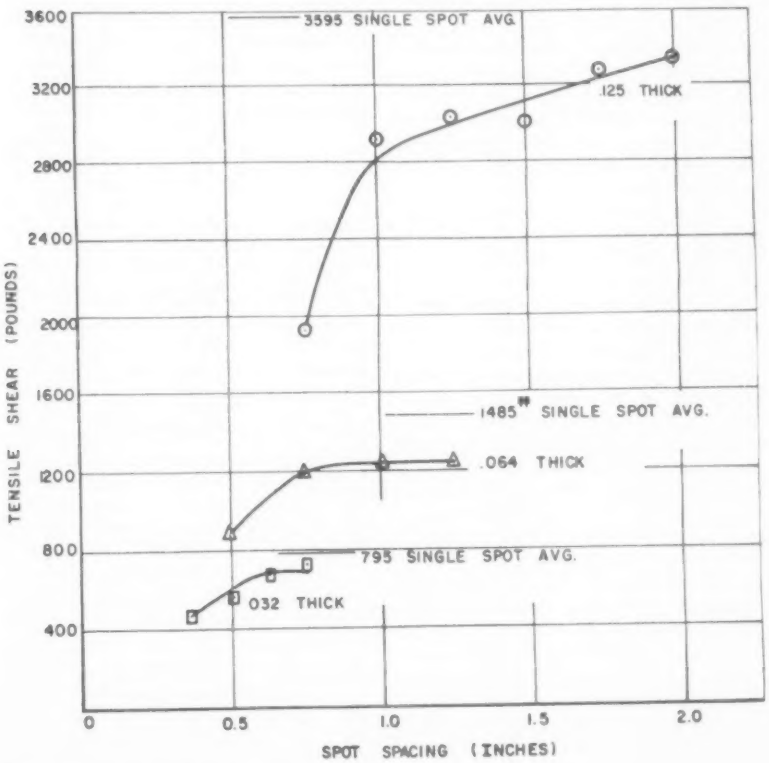


Fig. 10 Results of spot-spacing tests

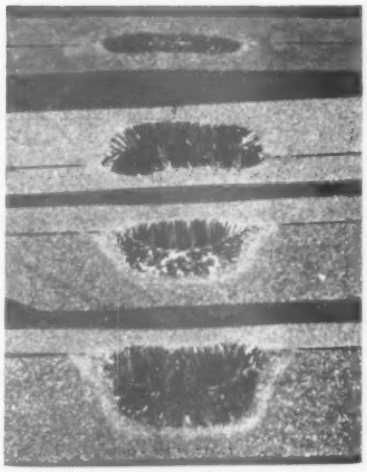


Fig. 11 Unequal thickness combinations

A piece of 0.032 thick yellow brass welded to each of four thicknesses: 0.032, 0.064, 0.094 and 0.125 in.
Etch: 3 parts Nitric Acid and 1 part Acetic Acid.

The anticipated shunting for any spot spacing can be obtained from the curves. All of the curves have a knee or definite change of slope. The minimum spot spacing allowed is a value just above the knee of the curve. When welding unequal thickness combinations, the minimum spot spacing should be equal to the minimum spacing recommended for the average thickness.

The determination of the minimum contact overlap is based on the ability of normal shop operators to be able to place the electrodes so that no bulging or expulsion occurs. If accurate fixturing is available for locating the electrodes, smaller contact overlap may be permissible. The bulging effect is replaced by edge cracks on the thicker gages. As shown in Fig. 9, 3/4-in. overlap produced an edge crack in 0.125 material. It even took some caution to place a spot weld on one inch wide coupons without producing an edge crack.

The minimum recommended spot spacing and contact overlap are listed in Table 3.

Unequal Thicknesses

Unequal thicknesses of yellow brass can be welded readily. All of the combinations of 0.032, 0.064, 0.094 and 0.125-in. thick material were welded with good success. In all cases, the minimum shear values were governed by the thinner member.

In unequal thickness combinations, additional consideration of electrode shape is required. As previously stated, one flat and one domed electrode were used. The domed electrode must be placed against the thinner member when unequal thickness combinations are welded.

Macro sections of 0.032-in. welded to each of 0.032, 0.064, 0.094 and 0.125-in. thick sections are shown in Fig. 11. As shown in the schedules of Table 4, it takes less current and a longer time to weld the 0.032-in. thick material to heavier thicknesses than it does to weld it to an identical thickness of 0.032.

Spot-Welding Schedules

Recommended spot-welding schedules are set up in Table 4 for thickness combinations from 0.032 minimum to 0.125-in. maximum. One major requirement of the schedule is that by adjusting current only, tensile-shear values can be attained with at least a 20% higher average than the minimum average required in Table 2. The schedule should also call for the minimum electrode force which will satisfy the tensile-shear values and also will satisfy the metallurgical and appearance requirements. A similar up slope setting is used for all combinations. It consists of three cycles of slope time with the initial current being 40% of the final current.

Conclusions

1. The hardness range for $^1/_2$ hard yellow brass should be divided into two ranges for spot weldability. The hardness range of Rockwell B65–74 requires more closely controlled welding conditions than the range of Rockwell B57–65.

2. Group A Class II electrode material is recommended for the spot welding electrode when welding yellow brass.

3. High electrode force will produce less penetration than low electrode force.

4. A short up slope time is recommended when welding yellow brass. A short time of three cycles and an initial current of 40% of the final welding current is recommended.

5. Unequal thicknesses as well as equal thicknesses of yellow brass can be welded with very good consistency. All thickness combinations for materials 0.032, 0.050, 0.064, 0.094 and 0.125 in. in thickness have been welded during the investigation covered in this paper.

6. Minimum contact overlap, minimum spot spacing and minimum tensile-shear values have been established for each thickness of yellow brass. These data are of value to the design, manufacturing and quality control departments.

7. Single-phase spot-welding equipment is applicable for spot welding $^1/_2$ hard yellow brass. Spot-welding schedules have been established for welding yellow brass on single-phase equipment.

RESULTS OF SOME BRITTLE FRACTURE TESTS

(*Continued from page 418-s*)

The entire assembly was cooled to +32° F. The center was cooled very locally to −58° F. A light tap with a hammer caused four cracks. The stopping temperature in CECM20 was +25 to +34° F with a large reduction in thickness. There was absolutely no reduction in thickness along the cracks in the patch.

(*e*) CECM25 was used for the ring, JSC25 for the patch. A hole $4^3/_4$ in. square was made in the center of the patch before welding. One corner of the hole was cooled to −4° F. A light tap with a hammer caused a crack at this corner and also at the opposite corner. The stopping temperatures were +3 and −2° F. The fact that a crack occurred at the opposite corner was remarkable, and illustrated the possibility of a crack starting without direct cause. A second specimen made entirely of JSC25 was tested. Spontaneous cracks occurred at the corner when the temperature was lowered to −54° F, the stopping temperature being +25° F. Cooling the opposite corner also caused a spontaneous crack with a stopping temperature of +32° F. Liquid air then was poured over the entire specimen. After a few minutes the existing cracks spontaneously propagated. The stopping temperatures were +23° F for the longest crack and −11 and −26° F for the shorter cracks.

(*f*) This specimen was made of CECM20 with an artificial defect welded in the center of the patch before it was lap welded to the ring. Measurements showed compression in the outer surface of the patch due to welding distortion. After the assembly was cooled to +14° F, the central defect was cooled locally. Two spontaneous cracks occurred and stopped in the patch, the stopping temperatures being +3 and −24° F. Further cooling of the defect caused the cracks to start anew, stopping in the outer ring at +18 to +5° F. The chevrons were eccentric. The lap joint did not act as a crack stopper.

(*g*) A specimen made of CECM20 with an artificial defect was stress relieved at 1200° F. The defect was cooled locally, but it required a violent hammer blow to cause a very small crack. Another stress-relieved specimen could not be cracked. The defect was heated locally to reintroduce shrinkage stress, after which local cooling with liquid air created a spontaneous crack.

These restrained-patch tests showed the ease with which cracks can be started when residual stresses are high. The artificial defect and particularly the square hole with sharp corners are excellent crack starters. Brittle fractures were observed in all steels starting at temperatures lower than the Charpy V-transition temperature for 15 ft-lb, but of the same order. The starting temperatures were lower than those

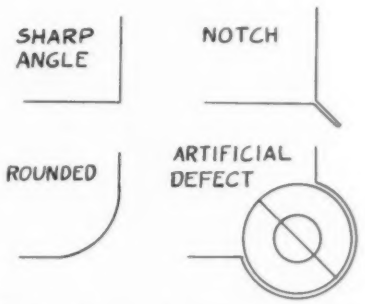


Fig. 3 Types of corners for biaxial stress tests of cross-shaped specimens

ever to be expected outdoors in Belgium. The stopping temperature was generally lower than the Robertson-arrest temperature.

Cross-Shaped Specimens

The cross-shaped specimen is shown in Fig. 2. The width of each branch of the cross was 8 in. Opposed sets of hydraulic jacks exerted biaxial stress on the specimen.

(*a*) A series of tests on specimens of CECM20 is summarized in Table 2. Fracture changed from ductile to brittle between −13 and −22° F, in good agreement with the Charpy V-15 ft-lb transition temperature. The notch was not very sharp at the root and had a stress-concentration factor of about 1.5. The notch therefore lowered the

(*Continued on page 432-s*)

EFFECT OF PLASTIC FATIGUE ON PRESSURE-VESSEL MATERIALS AND DESIGN

DISCUSSION BY J. J. MURPHY AND D. B. ROSSHEIM

The pressure vessel industry and many individuals concerned with pressure equipment design welcome the Report of the Coordinating Committee on Plastic Fatigue Strength of the PVRC Fabrication Division, which is so ably presented by the author in this paper.

Our comments are offered to stimulate further study and analysis in the preparation of a final report and are organized under three headings, namely: (I) Correlation of Fatigue Data with Tensile Properties, (II) Specific Comments on the Author's Presentation and (III) Future Work on Cyclic Effects.

I. Correlation of Fatigue Data with Tensile Properties

The author concludes that a large number of attempted correlations with various material tensile properties have failed to establish a valid basis for relating the fatigue properties of the Code accepted materials. It is mentioned that a literature survey was conducted to review available data relating tensile properties with fatigue life, the results of which are plotted in Fig. 4 which is restricted to machined and polished specimens. This figure indicates a close direct relationship with tensile strength. Reference is made in the text to Fig. 13 of Reference 7 but without indicating that this figure, showing results for mill surface and notched steel plates, shows appreciably less improvement with tensile-strength increase. The author discounts the usefulness of the University of Illinois flat-plate tests for practical interpretation purposes, particularly those of the unnotched plates, because of bulging. While this needs to be considered in interpreting the unnotched plate tests, the trend of the Illinois test results is too similar to that reported by Markl for bending tests on steel pipe, which were not subject to similar contour change effects and which were carried out over a broader range of cycles, to be discounted. Tests by Bailey[2] and Lane[3] also fit in with Markl's data. We would like to point out that:

1. Granting that cyclic loadings must be considered in pressure-vessel design, it follows that a correlation which permits effective use of present data and knowledge is as essential for pressure-vessel design and design principles as are nominal design allowable stresses. As with allowable stresses, we can profitably use the best basis which can be arrived at to date.

2. It appears that polished specimens may show a different correlation than bars having notches, mill surfaces or design local strain raisers.

3. Since cyclic design is concerned with the presence of notches, mill surfaces and local strain raisers, the correlation for design purposes should lend major weight to the behavior of specimens with notches, mill surfaces and representative design stress raisers rather than polished specimens.

4. A correlation associated with data from specimens which involve such stress raisers would result in a more restrictive but realistic basis for design, than one involving polished specimens.

5. It must be appreciated that the data on which any present-day correlation is based is extremely meager; also, that fatigue data unavoidably involve a substantial spread. Accordingly, the correlation basis selected must be utilized with a safety factor to take care of the data spread, as well as other variables. In other words, a correlation can be useful without a high degree of precision as associated with specific data, provided its use is tempered by a realistic appreciation of the data-range deviation from the selected base line. It is largely for this reason that a safety factor of ten is commonly applied to estimated cycles of life in present-day design.

It is our opinion that a correlation of fatigue based on some function of the tensile strength is entirely usable, and provides a necessary starting point for cyclic-life design. A next essential is agreement on a basis for integration of individual periods of varying operation into an integrated total as to fatigue demands (assessment of cumulative fatigue damage).

As an example of what might be accomplished by continued effort to establish a correlation of practical usefulness for design, the discussers have found that the following empirical expression for failure of material containing notches or similar local strain raisers in 100,000 cycles, shows reasonable correlation with Markl's data for steel pipe with welds, Forrest's[1] data for a wide variety of materials and also Illinois data (provided the stress range is multiplied by 1.25 as representing a possible correlation factor necessary to change from the failure criterion used to complete failure).

$$\text{Allowable strain range (in./in.) for failure in 100,000 cycles for plate with notches or equivalent stress raisers} = 0.0017 \sqrt{\frac{\text{UTS} \times 29 \times 10^6}{60{,}000 \times E}}$$

The allowable strain range for unnotched mill-surface pipe or plate would be approximately 1.5 times the above. The square-root correction factor also fits in well with the test data reported by R. W. Bailey.[2]

The authors have not been able to explore this thoroughly and offer it largely to stimulate further study. The fact that reasonable correlation was obtained with Forrest's data merits attention since this covered many materials at several temperatures and with widely different mechanical properties. It was noted that the performance of a hole as a stress raiser compared to a notch, did not show a constant relation, this formula correlating with the lower performance of the two.

II. Specific Comments on the Author's Presentation

In the introduction, the author points to long and successful experience with the safety factor of four as outmoding the former safety factor of five. To avoid misunderstanding, it should be pointed out that this was accompanied by refinement of design detail; such refinement is unnecessary for certain services of vessels, which with simpler details would be more economically constructed to a safety factor of five.

J. J. Murphy and **D. B. Rossheim** are associated with The M. W. Kellogg Co., New York, N. Y.

Paper by L. F. Kooistra was published in the March 1957 issue of THE WELDING JOURNAL, 36, Research Suppl., 120-s to 130-s.

The Code Committee is conscious of the fact that construction to the larger safety factor is not now satisfactorily covered by more generous design provisions.

Under "Importance of Plastic Fatigue Resistance" it is stated that fatigue strength has been recognized as of relatively minor importance in pressure-vessel failures. We question this conclusion since any failure on other than initial application of loading is a fatigue failure. It is generally appreciated that a great many failures occur at local areas of high stress, which areas are of significance from a standpoint of establishing the number of cycles to failure. It is also important that the interrelation of corrosion and fatigue be better appreciated and given much more consideration.

Under "Plastic Endurance" it is stated that for a relatively low number of expected cycles (approximately 10,000 and below), only the maximum strain range governs. . . . Is this not in general true of fatigue life regardless of the number of cycles to failure?

Under "Effect of Temperature" it is postulated that the improved fatigue life at elevated temperature is possibly increased tensile strength due to strain aging. An additional explanation would be the effect of temperature in reducing the modulus of elasticity and hence the elastic strain range. We have found that in comparing radically different materials, such as copper, aluminum, cast iron, etc., with steel, a correction for the modulus as well as for the tensile strength is necessary.

Under "Application of Fatigue Data" it is stated that the model vessel and nozzle attachment used at Ecole are too small to translate with confidence to full-size performance. This point deserves careful consideration in its influence on the interpretation of the present tests and similarly in its influence on future tests of this kind.

At the end of this section, it is concluded that membrane stresses can be of the order of one-third of the tensile strength without exposing the vessel to fatigue failure within 100,000 cycles. This statement is based on Table 6 which involves a strain magnification of four. The scope of the investigation to date certainly does not justify a conclusion that this is the maximum strain-raiser potential of designs which are currently acceptable under the Code. The author then emphasizes that a safety factor is not now provided, which assures against fatigue failure, and calls upon the Code-making bodies to establish such a factor. It is our opinion that, until sufficient data and guidance are forthcoming from the efforts of PVRC or industry, there is lacking a sufficient quantitative assessment of fatigue life for such bodies to closely establish such a safety factor. Also, such might be unduly restrictive for lesser cyclic services and unsafe for severely repetitive operation.

Under "Application of Design" and elsewhere in the paper, it is inferred that strain-concentration factors can be validly determined only experimentally and essentially for only the geometry and scale involved in a specific application. We are inclined to doubt the validity of this position and believe that any such conclusion arrived at with respect to the PVRC program to date is to be questioned on the basis of many other factors. The Ecole model tests should be examined closely for correlation with analytical stress concentrations, particularly failures at heads. It appears to the discussers that, for the cyclic pressure range used, the membrane strain range listed by the author is less than the circumferential strain the discussers calculate by elastic analysis. We question how this can be so. Also, triaxial strains exist at the ID, hence for valid interpretation and comparison with other data, equivalent strains utilizing the distortion-energy theory probably must be used.

Under "Application to Inspection" representative values are tabulated for the strain-raising effect associated with certain aspects. It should be emphasized that any such values are extremely approximate and subject to an appreciable range as associated with minor variations in contour and with relation to the general stress distribution of the structure in which they occur. Rounded and sharp radius nozzles may cover a wide range of design details with proportionate variation in the magnification in strain inherent to their geometry.

Under "Plastic Endurance vs. Material Characteristics" there is speculation as to whether a Lehigh-type specimen with a central hole might be advantageously substituted for the already used throated section. On fatigue tests in general, including those aimed at studying material properties alone, it is our feeling that a more reliable and wider appreciation of fundamentals and quantitative performance will be achieved where data are obtained from a number of different types of specimens, and tests are performed on various types of machines, involving not only different characteristics, but also a variation in the manner in which the load is applied. (See earlier comments re-Forrest's test data.)

We do not agree with the inference advanced by Item 2 under Geometry Factors in the Summary. Local stresses, such as at the intersection of two different surfaces of revolution can exist around the entire circumference and over a substantial area; also, the magnitude of local stresses can, in many cases, be analytically determined. Examples are—intersection effects, flange-hub stresses, head-knuckle stresses, etc. While stresses for nozzles cannot presently be determined analytically, it is not a valid assumption that general tests could not furnish a satisfactory basis for evaluation of the local stresses involved and thus avoid specific tests for each application. Perhaps it is intended that the wording here be associated with the thoughts expressed in the main body of the paper that specific tests are required.

From the third item under Geometry Factors in the Summary, it might be inferred that the magnification factor of four is the maximum which might be encountered with nozzles of the least favorable detail permitted by present Code rules, which is not the case.

The interest in pressure-vessel design exceeds the limitation expressed in the first paragraph in Cycling Conditions in the Summary. For example, nuclear-reactor design may involve a combination of temperature and pressure stresses under which widespread or membrane repetitive yielding occurs. Accordingly, it is necessary to know the magnitude of strain-concentrating factors extending into loading conditions where yield stresses may occur as applied to so-called membrane areas. This is also true of other services for better evaluation of the effect of emergency loadings.

III. Future Work on Cyclic Effects

We would suggest the following substitute recommendations for continuing the investigation of the significance of cyclic effects on pressure-equipment behavior.

1. Make a search of the literature on fatigue for contributions not only in the field of pressure equipment but all fields where materials are used under stress. This is to be done with the objective of benefiting from any information available on the fatigue behavior of materials which are used in pressure vessels. Included in this survey should be the contributions from abroad to the recent International Conference on Fatigue (ASME Annual Meeting, November 1956) and the papers relating to the fatigue tests of welds on structural plate performed at the University of Illinois. Of particular value would be any data which could be secured on wide strain ranges, the effect of various stress raisers, the effect of rate of loading, the effect of specimen details and size and the effect of mechanical properties.

2. Evaluate the information gained from Item 1 in conjunction with the PVRC tests, and expand the Plastic Fatigue Report covered by the author's paper, to reflect as nearly as possible the status of present knowledge on this subject. Make additional studies

and tests as indicated to be necessary by the survey for high strain ranges and attendant failure in a low or moderate number of cycles. Include low-ductility materials.

3. Perform a study of available knowledge and data to establish a consensus of present-day thinking as to the following aspects of cyclic behavior:

(*a*) Correlation of data with physical properties and spread of data as related to the criteria selected. In particular determine whether fatigue life in certain ranges is more validly related directly to the tensile strength or to the square root of the tensile strength, or some similar function of a tensile property. The author's Table 6 suggests allowable stresses which align closely with tensile strength. Section I of this discussion indicates a square-root relation may be more indicative of actual performance in the presence of the expected stress raisers.

(*b*) Assemble all available information on the effect of welds, with or without heat treatment or thermal stress relief, and for variations in surface finish and for the various types of defects.

(*c*) Assess present-day verification of the effect of mean stress, in particular in the plastic range.

(*d*) Assess whether a common correlation is possible for both polished bars, and for notched and mill surfaces, or whether separate correlation bases are necessary.

4. As a next step, make a survey to assess the aspects of cyclic behavior where additional information is required and establish long-range planning for an organized and logical, sequential approach in augmenting the background and data in this field. This would include:

(*a*) The significance of short-time ductility with time and temperature.

(*b*) For high-temperature cyclic loading, the interrelation between fatigue and creep, including the intermediate life range where both long and short time material properties are involved.

(*c*) The influence of local strain magnifications for service at elevated temperature under the combined influence of short-time cyclic effects and long-time cyclic effects which involve creep.

(*d*) The effect of cycle duration on the repetitive application of temperature and loading at room and elevated temperatures.

(*e*) The effect on creep rate and creep-rupture life of cyclic and varied temperatures and loadings.

References

1. Forrest, P. J., "Influence of Plastic Deformation on Notch Sensitivity in Fatigue," ASME November 1956 Annual Meeting.
2. Bailey, R. W., "Usefulness and Role of Repeated Strain Testing as an Aid to Engineering Design and Practice," ASME November 1956 Annual Meeting.
3. Lane, P. H. R., "Fatigue Tests on Seamless Mild Steel Pipe Bends," ASME November 1956 Annual Meeting.

AUTHOR'S CLOSURE

Messrs. Murphy and Rossheim's comments reflect the tremendous amount of work and thinking they have done on the subject of codifying allowable stresses and strains in pressure vessels and piping. They cover a field of broader scope and complexity than plastic fatigue, and to reply in detail, I am sure, would confuse and bury the rather simple message of the paper. I will, therefore, touch upon only a few of the pertinent comments. Messrs. Murphy and Rossheim feel that plastic fatigue can be correlated with tensile strength. This appears possible only at the higher number of life cycles. At the lower number of life cycles ($N = <10{,}000$ cycles) the initial tensile characteristics have no effect at all on the allowable strain.

With increasing magnitude of the strain, the effect of TS approaches the vanishing point. This is probably reflected in the suggestion of the discussers (based on correlation of the meager data available) to use the square root of the TS. The use of a fractional power diminishes the influence of a factor. Indications are that, depending on the cycling range chosen, it will be possible to produce data to show the effect of TS from a zero power at the low-cycle range to unity at the high range of conventional fatigue. This broad variation of the effect of TS (TS^0 to TS^1) renders it of very doubtful value as a true parameter and serves to show the difference between plastic and conventional fatigue.

If we are to utilize the plastic strength of pressure-vessel materials, it is therefore necessary to develop a measuring stick that is pertinent to the characteristic we want to measure in the same manner as has been provided for other material characteristics in the past, such as the hardness test, the impact test, the creep test. It appears, therefore, quite logical that in order to determine the plastic strength of a ductile material, we should measure its plastic endurance. This should preferably again be done with the most simple specimen that can be correlated with actual performance.

The discussers question the accuracy of the strains measured on the vessel models. The actual data were again checked at Ecole Polytechnique and the results are presented in Table 1 and Table 2:

With the exception of one 7% discrepancy the calculated and experimental values are in close agreement. The apparent discrepancy between experimental strains and pressure data may be explained by the fact that only simple strains on the outside were measured and reported whereas the inside strains would have been more pertinent, as all failures started on the inside surface. The inside surface on these particular specimens, however, was not readily accessible for these types of measurements. The larger specimens contemplated for future tests will be accessible on the inside and will overcome this limitation.

Table 1—Comparison of Calculated and Experimental Strains

		External surface				*Internal surface*
		Circumferential strain, %		*Longitudinal strain, %*		
Vessel	*Maximum cyclic pressure, psi*	*In Tables 2 and 5 of paper*	*Calculated strain**	*Experimental strain*	*Calculated strain**	*Experimental strain*	*Calculated circumferential strain, %*
G((A-201)	3675	0.074	0.079	0.078	0.018	0.021	0.092
H(A-201)	3300	0.066	0.071	0.072	0.016	0.018	0.082
L(A-302)	6800	0.145	0.146	0.152	0.034	0.033	0.169
M(A-302)	5700	0.122	0.122	0.141	0.028	0.037	0.142
P(A-302)	4950	0.105	0.106	0.111	0.024	0.027	0.123

Table 2—Comparison of Calculated and Experimental Stresses

Vessel	Maximum cyclic pressure, psi	External surface: Circumferential stress, psi — Calculated stress* (Lame formula)	External surface: Circumferential stress, psi — Experimental stress	External surface: Longitudinal stress, psi — Calculated stress* (Lame formula)	External surface: Longitudinal stress, psi — Experimental stress
G(A-201)	3675	27,800	27,750	13,800	14,600
H(A-201)	3300	25,000	25,500	12,400	13,200
L(A-302)	6800	51,500	53,200	25,600	25,800
M(A-302)	5700	43,200	43,600	21,400	23,200
P(A-302)	4950	37,500	39,400	18,600	19,900

* NOTE: Assuming wall thickness is exactly 3/4 in., ID = 12 in., OD = 13 1/2 in. and neglecting slight flexure in middle of shell due to its length not being infinite.

A number of the suggestions on future work are in line with what has already been done. A search of the literature has revealed an almost complete lack of data on low-cycle fatigue. The ASME International Conference on Fatigue yielded Reference 12 of the paper, which was valuable information. The paper by R. W. Bailey referred to described a testing method similar to the one used at Lehigh and limited data on two steels.

The task of investigating a complex problem of this type is to condense from the many things that should be done, those that are most pertinent and can be done with the limited funds available. A comprehensive attack on all of the phases will require full-time effort and more financial support than is generally realized to be necessary by those not familiar with the cost of research and several times more than has been made available to PVRC.

To make full use of the plastic strength of the pressure-vessel structure, we have to know the plastic endurance of the material of construction and the plastic behavior of materials at points of strain concentration. Simple, pertinent tests must be developed to give a measure of these characteristics. The work of PVRC reported here is the first step toward this goal.

Extending the work of analytical and experimental stress analysis into the plastic range on specimens representative of full-size vessels, will give a measure of plastic endurance required by various design components. From these data the full range of capability of the material and the structure in a vessel can be determined with a realistic margin of safety.

RESULTS OF SOME BRITTLE FRACTURE TESTS

(*Continued from page 428-s*)

fracture stress. A plastic zone was observed at the root of the notch where fracture started. The lower the temperature, the smaller was the plastic zone.

(*b*) Robertson tests made with biaxial stress showed that the Robertson-arrest temperature was the same as under uniaxial stress.

(*c*) A comparison of four types of stress raisers, Fig. 3, was made in two steels 3/4 in. thick having a tensile strength of 60,000–71,000 psi. The results are given in Table 3. In general the transition temperatures are less favorable than the Charpy V-15 ft-lb transition temperatures, which were +43 and −4° F. These results confirm the importance of eliminating notches in highly stressed structures.

Table 3—Transition Temperatures Determined for Cross-Shaped Specimens

Type of corner	Temperature at which fracture changes from brittle to ductile, ° F
Sharp	+90 to +111
Notched	+86
Rounded	below +45
Artificial defect	+18 to +70
Sharp, but high quality steel	+14 to +32

(*d*) Three structural steels (60,000–71,000 psi tensile strength) were tested as crosses with sharp corners, Table 4. The brittle + ductile fractures started brittle, but became ductile before final failure. The Charpy V-transition temperatures class these steels in the same order as the cross test.

These tests show that notches or notch-like defects favor brittle failure and that residual stresses magnify the effect of defects.

Table 4—Cross-Shaped Specimens of Three Structural Steels

Steel*	Transition temperature,† ° F	Manufacture	Temperature of Test, ° F	Fracture stress, psi	Elongation, %	Type of fracture
C15	−44	Open hearth	−72	62,500	5.10	brittle
C15	−44	Open hearth	−54	57,000	5.10	ductile
C15	−44	Open hearth	−31	53,500	5.04	ductile
C15	−44	Open hearth	− 4	52,500	4.50	ductile
B15	+19	Basic Bessemer	+27	42,000	2.10	brittle
B15	+19	Basic Bessemer	+41	39,000	1.90	brittle
B15	+19	Basic Bessemer	+46	38,500	3.42	brittle + ductile
B15	+19	Basic Bessemer	+59	41,500	3.08	brittle + ductile
B20	+50	Basic Bessemer	+72	44,000	2.28	brittle
B20	+50	Basic Bessemer	+82	45,000	2.05	brittle
B20	+50	Basic Bessemer	+91	42,000	4.05	brittle + ductile

* 15 = 0.59 in. thick; 20 = 0.79 in. thick. † 15 ft-lb Charpy V.

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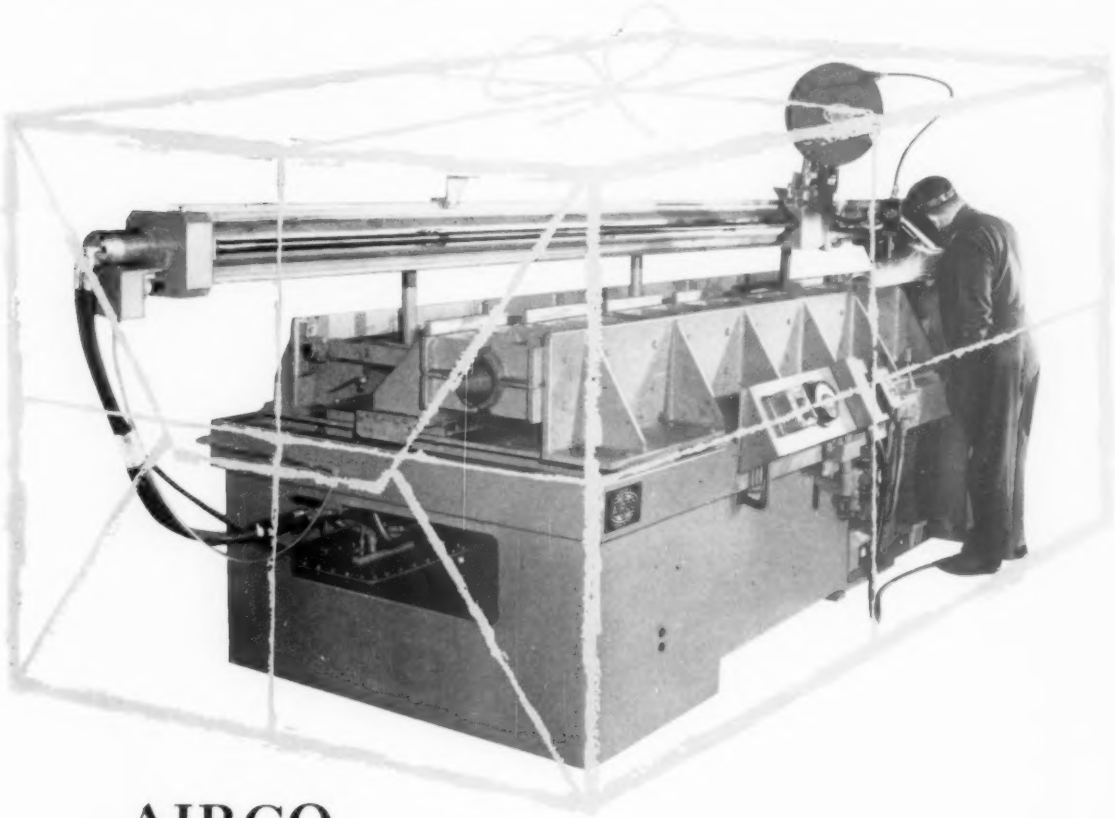

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